Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

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2/- APR., 1944

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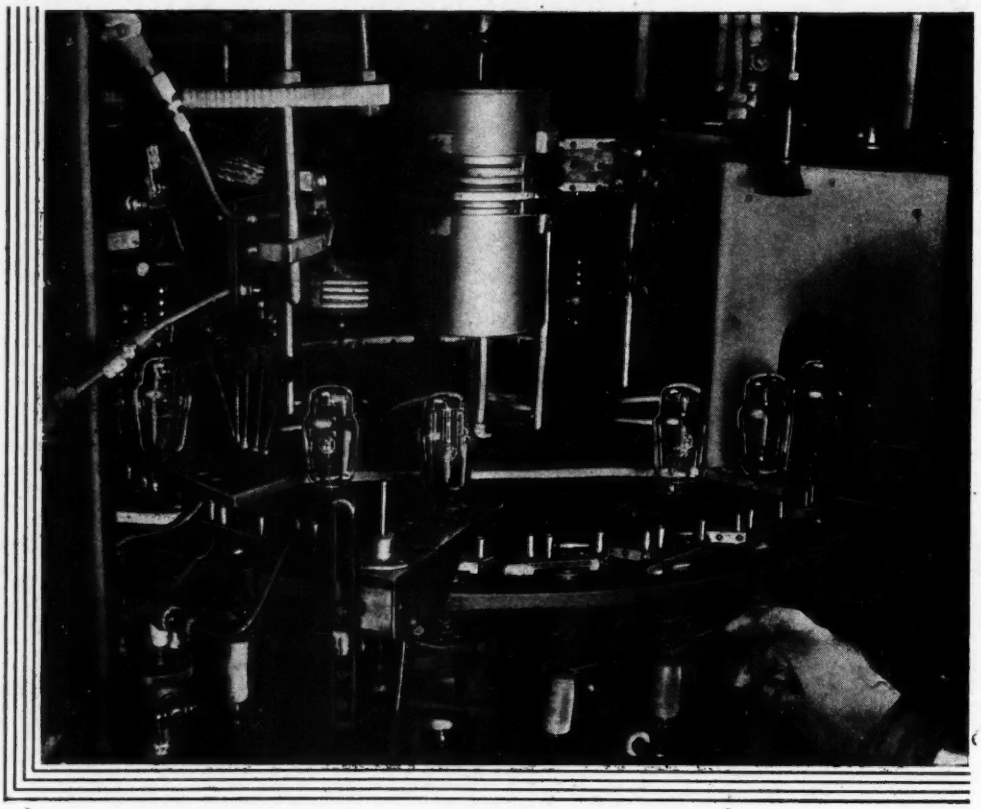

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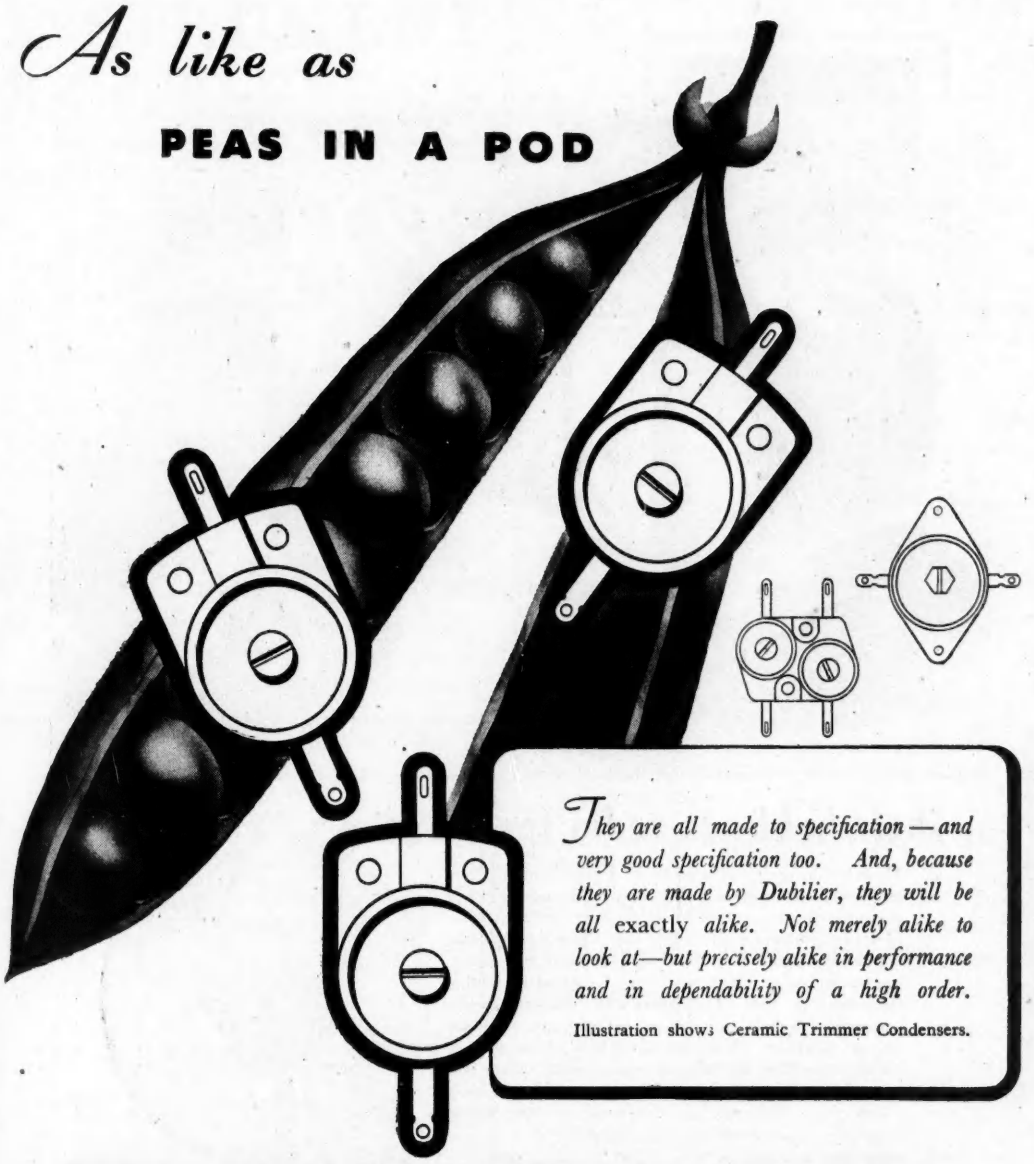

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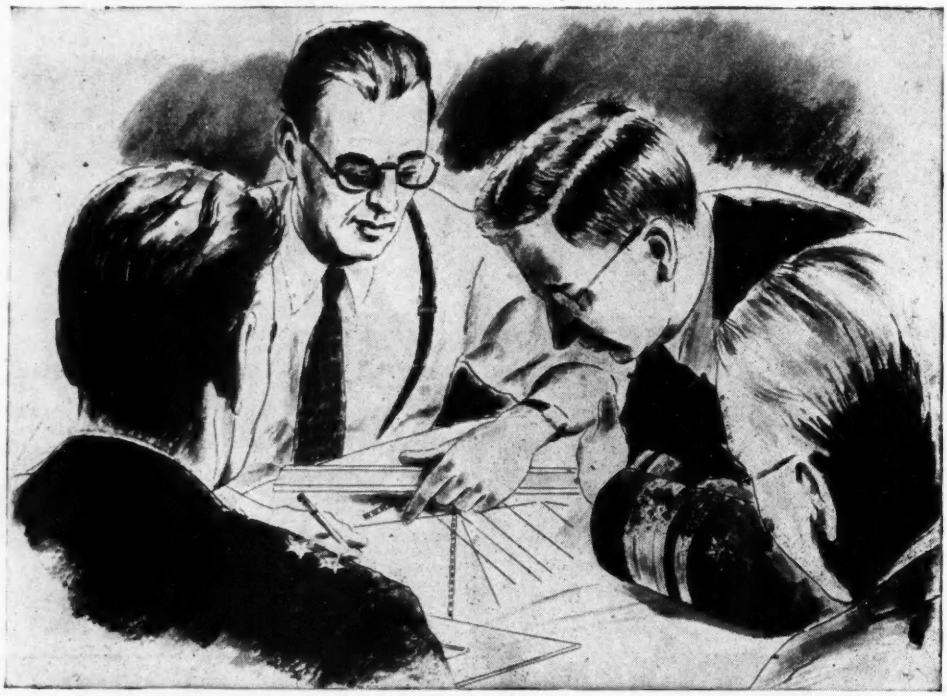

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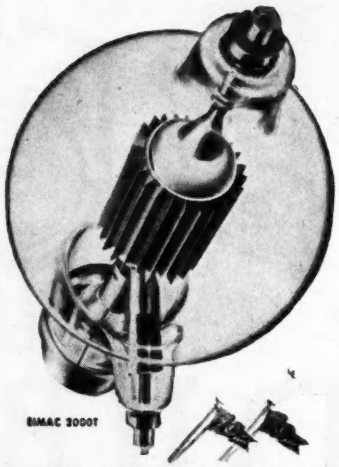

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Electronic Engineering

APRIL, 1944

Volume XVI. **No. 194.**

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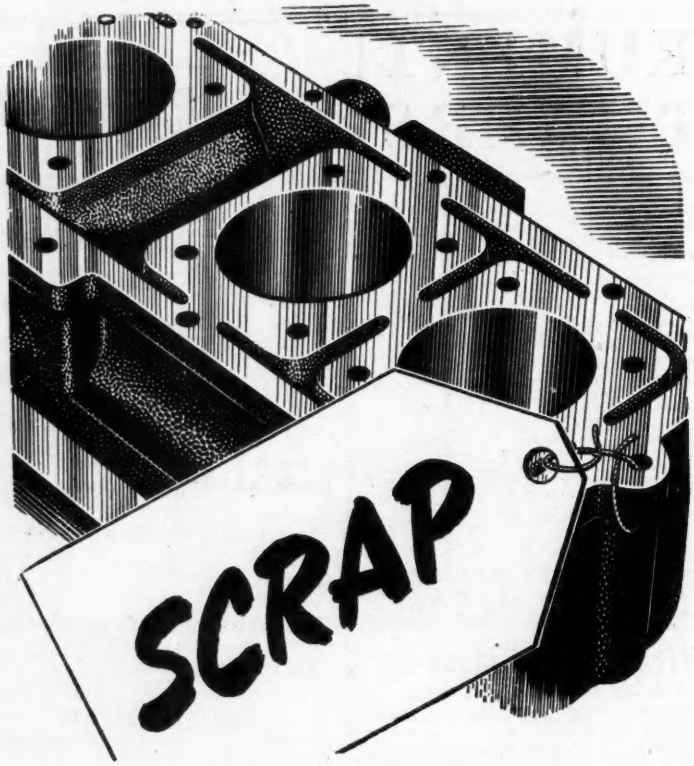

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Simplification

SOME time ago on this page attention was drawn to the standardisation of resistance values by the manufacturers of fixed resistors, and the hope was expressed that this would encourage the simplification of other ranges of components.

Our American contemporary, *Electronic Industries*,* in its January number gives some astonishing figures of the simplification which has been made in civilian radio components over there. Under pressure of wartime production 2,700 different types of volume controls have been reduced to 12; 400 types of electrolytic condensers have reduced to 10; 280 transformer types to 12, and so on.

In an article in the same issue the Assistant Director of the Radio Division, War Production Board, tells of a condenser manufacturer who boasts of having 300,000 different specifications in his plant, 115,000 of which are in active military use. These could be cut down to 300 with suitable standardisation.

He quotes the actual case of a bomber which left the airfield on an important mission without its u.h.f. gear working satisfactorily for lack of a spare condenser in the Air Corps stores. After the crew and bomber had been reported lost it was found that the Navy had similar condensers in stock under a different code number at the same base!

Commander D. R. Hull (U.S. Navy) says that the U.S. Navy Bureau realise that electronic designers have for years been schooled to aim for perfect performance from each circuit, and frequently this striving for perfection has resulted in assembling circuits that not only meet the required performance characteristics but surpass it.

He suggests that the time has come to examine each proposed design with a view to the ultimate production of the simplest possible functionally satisfactory equipment.

While such statements meet with applause in wartime, it is interesting to reflect that the coming of peace will bring with it a gradual drifting back to the days of unlimited types and minute variations. The designer who wants his apparatus to be just that little better than the others is not going to be tied down by limitation of types, and, human nature being what it is, he will always find a manufacturer willing to give him what he wants.

One solution to the problem might be a two-price level—the simplified range being mass-produced at a low price to encourage its use, and the special components with frills being surcharged to discourage their adoption. A scheme of this nature has, of course, been in force for some years among the lamp manufacturers and might be extended to the valve manufacturers.

Another point is that the components and accessories which are fundamentally satisfactory and which are only capable of alteration without improvement should be rigidly limited in type numbers. As a case in point, Mr. G. A. Jones in a recent discussion† stated that the Kodak Co. manufactured about 150 different types of recording material for oscillographic work. It would surely be possible to agree on a standard range of film and paper which would meet all requirements and regretfully decline to provide variations.

But it is easy to talk—the electrical fittings manufacturers still make dozens of different power plugs in spite of the efforts of the B.S.I., and the travelling demonstrator still has to carry a bag of assorted adaptors!

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* Jan. 1944, p. 100.

† At the Association for Scientific Photography.

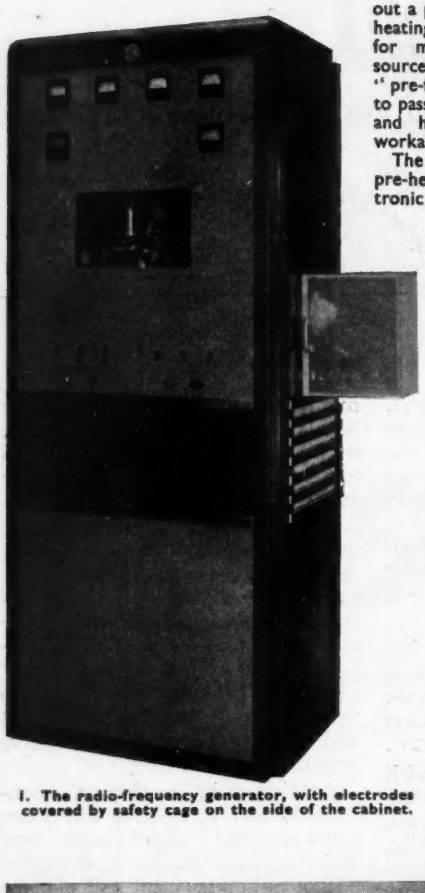
Electronic Pre-heating in Plastic Moulding

The desirability of uniform heating throughout a piece of material is found in the pre-heating of plastic materials to prepare them for moulding. Heat from conventional sources must penetrate the raw material "pre-form" from the outside, which tends to pass through the desired "tacky" stage and harden before the inside becomes workable.

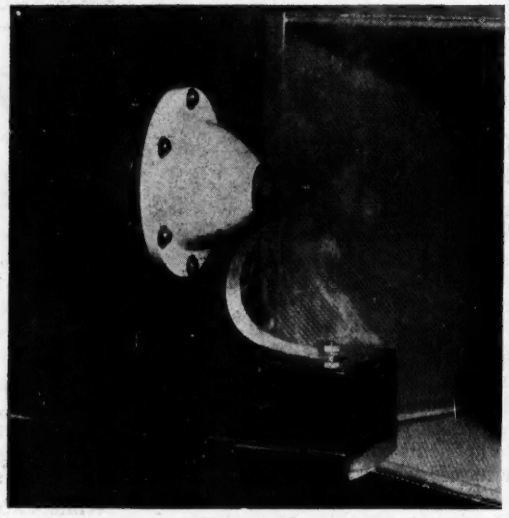
The use of radio-frequency current for pre-heating, made possible by new electronic devices developed by the Radio Corporation of America, eliminates this difficulty. When pre-forms are placed between the electrodes of this device, heat is generated within the material itself, with the result that they are heated quickly and uniformly throughout.

The nature of the equipment and the speed with which it generates heat, make it possible to perform many heating operations on a mass production basis, utilising the continuous process principle of the conveyor belt.

—*M. Lorant.*



1. The radio-frequency generator, with electrodes covered by safety cage on the side of the cabinet.



3. A close view of the electrodes with pre-forms in position between them.

2. Two pre-forms of raw material before heating.

4. A finished plastic outlet box as it comes from the mould.

Cosmic Rays

By Dr. L. JÁNOSSY*

A Lecture delivered before the Electronics Group of the Institute of Physics, London.

AT the beginning of the century it was shown simultaneously by C. T. R. Wilson and by Elster and Geitel that a charged electroscope placed inside an earthed metal box gradually loses its charge, however carefully it is insulated.

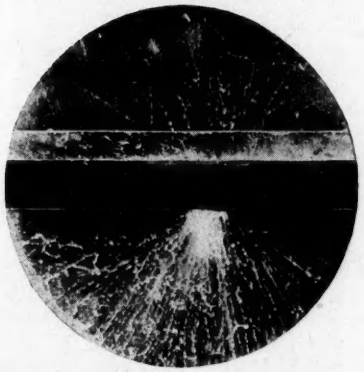
It was found that the conductivity was due to an ionising radiation. C. T. R. Wilson suggested tentatively that the radiation responsible for the ionisation might be a penetrating radiation coming from outside space. Experiments carried out to test this suggestion failed, and the hypothesis of the extra terrestrial origin of the ionising radiation was temporarily dropped.

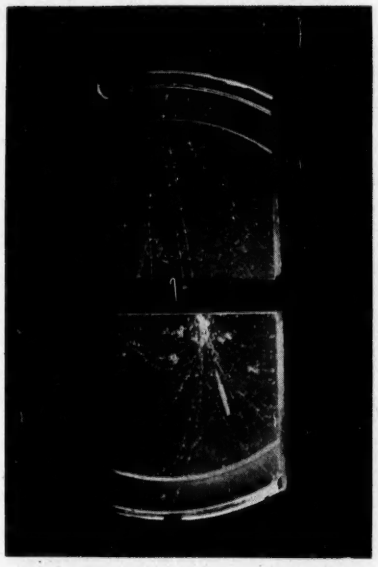
Ten years later, however, Hess and others, ascending in balloons, measured the rate of ionisation in closed vessels up to a height of nearly 10 kilometres. At high altitudes the ionisation was found to increase considerably. These results were interpreted as showing that ionisation at high altitudes was due to a radiation coming from above and originating outside the atmosphere. This radiation, now called cosmic radiation, penetrates down to sea level and also far below the surface of the ground. But whilst most of the ionisation of the atmosphere at high altitudes is due to cosmic rays, only a small fraction of the ionisation near the ground is due to them, the greater part being of radio-active origin.

The Origin of Cosmic Rays

Immediately after their discovery it was realised that cosmic rays are likely to come from outside space and do not originate in the upper atmosphere. The extra-terrestrial origin was assumed because cosmic-ray intensity varies with geo-magnetic latitude. This variation was interpreted by assuming that cosmic ray particles are approaching the earth from far outside and are deflected by the earth's magnetic field. If cosmic rays had their origin in the upper atmosphere and not in outside space the earth's magnetic field could not appreciably affect them. Thus the observed geo-magnetic effects provide conclusive evidence for an extra-terrestrial origin.

The bulk of cosmic rays do not come from the sun, as otherwise a pronounced 24-hour period of radiation intensity must be expected. Actually a 24-hour period was observed but the amplitude of this period was too small to justify the assumption of a solar origin.





Figs. 1a, 1b. Photographs of cascade showers. The cloud chamber is divided by a lead absorber. It is seen that the incident particles produce many secondaries in traversing the plate. *(J. G. Wilson and A. C. B. Lovell)*

An interesting theory was proposed by Compton and Getting. It was pointed out that if cosmic rays have their origin outside our galaxy then the rotation of our galaxy would give rise to a Doppler effect which would cause a variation of intensity with sidereal time. A variation not unlike that expected to result from galactic rotation was, in fact, observed. Nevertheless, as the theory encounters various difficulties it cannot be regarded as established. Almost nothing is known about the process by which cosmic rays are generated. The fundamental difficulty is connected with the large energies of some cosmic ray particles. The average cosmic ray particle has an energy of about 1,000 MEV, but particles with energies of 10^{10} MEV and probably much more are known to occur. Such large energies cannot be generated in processes involving the interaction of single elementary particles. The highest amount of energy known to be concentrated in one single particle is the rest energy of the proton or neutron amounting to 1,000 MEV. Thus, unless one postulates processes in which millions of protons are annihilated in one single act, one cannot account for the high energy cosmic rays in terms of the energy liberated in processes where elementary particles interact. The simultaneous annihilation of several protons is very unlikely on general grounds.

It may therefore be assumed that cosmic rays are not generated in atomic or nuclear processes but are probably due to some cosmological process. In this connexion it is of interest that the average energy loss of a cosmic ray when traversing the whole of our universe is small compared with its original energy. It was suggested by Lemaitre that cosmic rays are the remaining " ghosts " of a period of the universe long past.

An interesting attempt to account for cosmic rays in terms of well-known processes was made by Alfvén. He pointed out that the components of a double star if possessing magnetic dipole moments might act as a large cyclotron generating high speed particles.

The Nature of Cosmic Ray Particles

The primary cosmic ray beam undergoes complicated transitions when traversing the atmosphere. In the following we discuss the nature of the radiation at sea level.

At sea level three components are found: (1) the soft component which will be shown to consist of electrons and photons; (2) the hard component consisting of mesons, *i.e.*, particles of electronic charge but masses intermediate between those of the electron and the proton; (3) a very weak com-

* The University of Manchester.

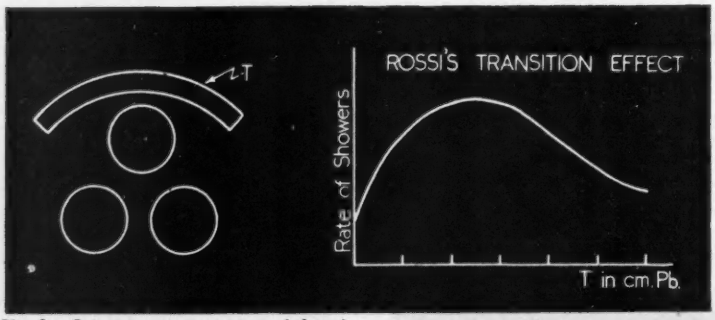


Fig. 2. Counter arrangement used for the observation of showers.
Fig. 3. Rossi's shower transition effect.

ponent which is believed to consist of fast protons and neutrons. To give the reasons which led to the above classifications of the cosmic ray particles it will be necessary to give a brief account of some aspects of the theory of fast particles.

(a) *Charge and Velocity.*—The density of ionisation produced by a particle of charge e and velocity v is given approximately by

$$I = e^2/v^2 \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

According to the theory of relativity the velocity of a particle tends toward the velocity of light when the energy and the momentum of the particle increase indefinitely. Thus, for particles with high energy or momentum the ionisation density as given by (1) tends to a limiting value. This limiting value of the ionisation is the same for different particles provided they carry the same amount of electric charge.

Eqn. (1) is only approximately correct. The actual density of ionisation increases logarithmically with energy for high energies. In the following we shall neglect that increase.

The rate of ionisation for fast particles with electronic charge is about 40 ion pairs per cm. of air at N.T.P. The track produced by such a particle in a cloud chamber appears as a fine line, and it may be called a light track. The track of a slower particle shows a larger density of ionisation and it may be called a dense track. Most of the cosmic ray particles observed in a cloud chamber give rise to light tracks and can be identified as particles with electronic charges and velocities approaching that of light.

The sign of the charge of particles can be determined when the particles are deflected in a strong magnetic field. It is found that cosmic rays contain almost equal numbers of positively and negatively charged particles with a small excess of positively charged ones.

(b) *Mass.*—The momentum of a particle can be determined by measuring the curvature of its track in a strong magnetic field. The momentum of a particle with the rest-mass m_o and velocity v is given by

$$P = m_o v/(1 - v^2/c^2)^{\frac{1}{2}} \quad \ldots\ldots \quad (2)$$

For $v = c/\sqrt{2} = 0.71c$, $P = m_o c$. Thus for velocities $v \sim c$ the momentum exceeds $m_o c$. Thus from equations (1) and (2) one concludes that light tracks will be due to particles with momenta exceeding $m_o c$. Numerical values of $m_o c$ are collected in the following table:—

Particle	Mass in Units of the electron mass	$m_o c$ in MEV/c
Electron	1	0.52
Meson	180	100
Proton, Neutron	1800	1000

Thus electrons will give rise to light tracks when exceeding 0.5 MEV, mesons when exceeding 100 MEV, and protons when exceeding 1,000 MEV.

Cloud-chamber photographs were found frequently to show light tracks of particles with a magnetic deflection corresponding to a momentum of 1 MEV or less. Tracks of this kind must be due to electrons. It was shown by Anderson and also by Blackett that electron tracks show both positive and negative curvatures. This led to the discovery of the positive electron.

(c) *Radiative Collisions and the Soft Component.* According to the theory of Bethe and Heitler electrons traversing matter lose much energy by emitting photons in collisions with atomic nuclei. An energetic electron when traversing 0.5 cm. of lead or 3 cm. of iron is expected to lose the greater part of its energy to photons. The photons emitted are absorbed quickly each giving rise to an electron pair by the simultaneous creation of a positive and negative electron. An energetic electron falling on an absorber will thus give rise to one or more energetic photons, the photons will again produce electrons, and the cascade started by the primary electron goes on producing more and more electrons and photons until the energies of the electrons have become so low that they are brought to rest by ionisation loss.

Thus an electron falling on a lead absorber of, say, 2 cm. thickness will either be stopped completely or will give rise to a cascade in the absorber and a number of electrons will emerge out of the bottom of the absorber.

Cascades of this kind are found frequently on cloud chamber photographs. Examples are reproduced in Figure 1. Indirect evidence for the occurrence of the cascades is also obtained by counter experiments. The experimental arrangement used by Rossi is given schematically in Fig. 2. Three counters are placed in a triangle and a record is made whenever they register the simultaneous passage of cosmic ray particles. A single particle can pass only through two out of the three counters and therefore threefold coincidences are due only to showers, *i.e.*, groups of two or more simultaneous particles.

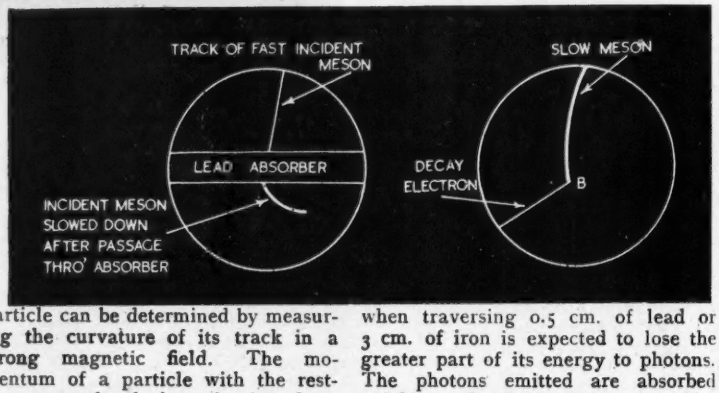


Fig. 5. Schematic drawing of cloud chamber photograph showing a fast meson entering a lead absorber. After the passage through the absorber the meson is slowed down and gives rise to a dense track. The curvature of the slow meson track is due to a magnetic field applied to the chamber.
Fig. 6. Schematic drawing of a cloud chamber photograph showing a decaying meson. The slow meson is entering the chamber and is giving rise to a dense track. The meson is brought to rest in the point B. The decaying meson emits a fast electron giving rise to the light track emerging from the point B.

In Figure 3 the rate of showers recorded with a triangular arrangement is plotted as function of the thickness of the lead absorber T placed close above the counters. It is seen that the rate of coincidences increases first with increasing thickness of absorber, reaches a maximum near to 2 cm. thickness and then decreases again at larger thicknesses. This transition effect can be understood in terms of electron cascades. The initial rise and the later fall of the shower rate is closely related to the development and subsequent absorption of cascades due to electrons falling on T.

The photographs of cascade showers and the discussion of the Rossi-transition effect give conclusive evidence for the occurrence of energetic electrons in the cosmic ray beam and for the validity of the theory of Bethe and Heitler for high energy electrons and photons.

(d) *Penetrating Component.*—A cloud-chamber photograph of a particle which does not behave like an electron is seen in Figure 4. The particle is seen to traverse a lead plate 2 cm. thick without giving rise to secondaries. The measurements of the curvatures of the track above and below the plate showed that the particle traversed the plate without losing much of its energy.

It was found that about 80 per cent. of the particles incident are more penetrating than electrons.

The radiative loss of energy suffered by electrically charged particles can be shown to vary inversely with the square of the rest-mass of the particles. Thus it must be expected that the penetrating particles encountered in cosmic rays are particles heavier than electrons. It might be suggested that the penetrating particles are protons. This is, however, not the case for the following reasons. Firstly, penetrating particles are found both with positive and negative charge, while if they were protons they ought to be all positive. Secondly, protons with momentum less than 1000 MEV are expected to give rise to dense tracks, while penerating particles with momenta well below 1,000 MEV are observed showing light ionisation only. Thus lightly ionising penetrating particles must be expected to have rest-masses between those of the electron and proton.

These indirect conclusions can be confirmed by the observation of dense tracks with a curvature corresponding to momenta somewhat below 100 MEV. An example of such a track obtained by Anderson is shown schematically in Figure 5.

These particles are called mesons

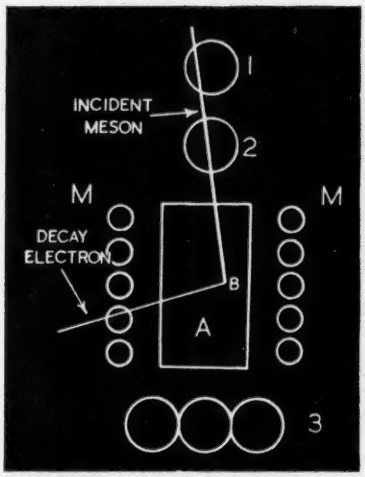


Fig. 7. Scheme of the arrangement used for the measurement of the half life of the meson. The incident meson discharges the counters 1 and 2 above the absorber A but is stopped in the point B and does not discharge any of the counters 3. The decay electron emitted discharges one of the counters M. The delay between the anticoincidence 1, 2, 3 and the discharge of the counter M is equal to the time the meson spent in the absorber.

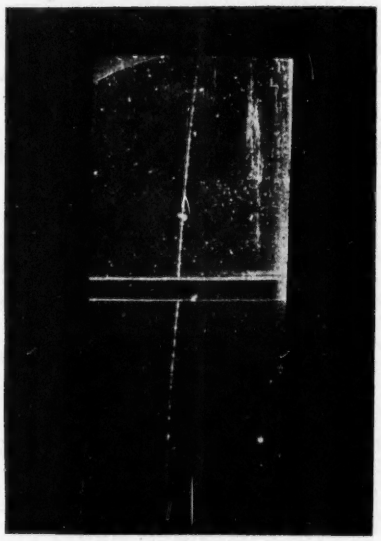


Fig. 4. Cloudchamber photograph of a meson traversing a lead plate. (Blackett)

(sometimes mesotrons). The value of the rest-mass of mesons can be determined from photographs of slow mesons. The velocity can be estimated by means of eqn. (1) from the rate of ionisation observed along the track; while the momentum can be derived from the curvature of the track. Introducing P and v into eqn. (2) m_e can be determined. It may be noted that only the tracks of slow particles are suitable for the determination of the rest-mass since the density of ionisation of a fast particle is almost independent of its rest-mass.

Tracks of slow mesons are obtained only rarely and therefore the mass of the meson has not yet been determined accurately. All available evidence is compatible with a meson mass of about 200 electron masses. The exact value is, however, unknown and it can not even be taken for granted that all mesons have the same rest-mass.

The Instability of the Meson

(a) Guided by considerations connected with the theory of β-decay Yukawa was led to postulate the existence of a particle with the following properties (1) the particle was expected to have a mass of about 200 times that of the electron and to have a positive or negative electronic charge; (2) the particle was supposed to be unstable and to decay after a half life time of about 10^{-6} seconds into an electron and a neutrino. It was suggested by Yukawa that particles of this kind might be found among cosmic rays.

Some years after the theory of Yukawa was put forward the meson was discovered amongst cosmic rays. As we have seen in the previous section the cosmic ray meson has about the same mass as that predicted by Yukawa for his hypothetical particle. In the following we shall show that the cosmic ray meson is unstable and has a half life of about 2×10^{-6} secs. Thus the cosmic ray meson must be identified with the particle predicted by Yukawa.

E. J. Williams obtained direct evidence for the instability of the meson from a photograph which is schematically shown in Fig. 6. The photograph shows a slow meson entering the chamber giving rise to a dense track. The track ends in the gas and from the end of the dense track a thin track emerges. The thin track is due to the decay electron. The decay electron is fast as it takes half the rest energy of the meson, *i.e.*, 50 MEV. The remaining half of the rest energy is supposed to be taken by the neutrino. The neutrino having no charge does not give rise to a track in the chamber.

The value of the half life of the meson was measured directly by Rossi and by Rasetti. The experimental arrangement is shown in Fig. 7. An absorber A is between the counters of an anticoincidence arrangement. The anticoincidence arrangement responds whenever a particle enters the absorber A traversing the counter 1 and 2 but is stopped in the absorber and therefore does not

traverse any of the counter 3. Mesons stopped in A are therefore recorded by anticoincidences. Whenever an anticoincidence is recorded the counters M surrounding the absorber A are made sensitive for a short time interval. The counters M thus register particles entering them shortly *after* anticoincidences have taken place. The electrical recorder is so arranged that the time of delay between anticoincidence and the following discharge of the counters M is recorded. If a meson is stopped in A giving rise to an anticoincidence and if the meson after having been brought to rest in the absorber A decays emitting an electron, the electron will be registered by the counters M and the delay will be recorded. A large number of mesons were thus observed, and it was found that the number of mesons spending more than the time t in the absorber was given by.

$$N_t = N_o e^{-t/t_o}$$

with $t_o = (2.15 \pm 0.1) \times 10^{-6}$ sec. ..... (13)

The relation (3) shows that mesons decay at random times like radioactive nuclei; t_o is the average life time of the meson.

b. The average path length of a meson is not given by the product of life time and velocity.

$l = vt_o < ct \approx 700$m ..... (5)

as it might be assumed. According to the theory of relativity a clock moving with a velocity v towards the observer appears to lose time at a rate of $1 : (1-v^2/c^2)^{1/2}$. The meson can be regarded as a clock and therefore life time as observed from the earth is expected to be

$t'_o = t_o/(1-v^2/C^2)^{1/2}$ ..... (4)

and therefore the average length of path L, a meson of momentum P can cover before decaying is obtained with help of equns. (2) and (4) as

$L = t'_o v = ct_o(P/m_o c)$

$\approx 0.7\ P/1000$ MEV km ... (5)

The experimental evidence shows clearly that the range of fast mesons is given correctly by the relativistic formula (5) and not by expression (5'). Indeed it is known that the mesons observed at sea level are formed at heights exceeding 16 km. If equation (5') were correct one should expect that only few of the mesons formed at that height would be capable of reaching sea level. On the other hand, according to the relativistic formula (5) mesons with energies 2,000 MEV or more have sufficiently long average ranges to reach sea level. Thus one has to accept the relativistic time contractions in order to explain how the bulk of the fast mesons can reach sea level.

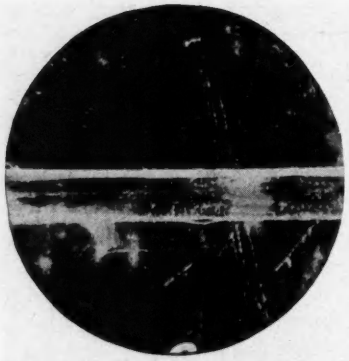


Fig. 8. Cloud chamber photograph showing the tracks of three mesons presumably created in a single act.
(Janossy, McCusker and Rochester)

c. The relativistic time contraction can also be verified quantitatively from the observation of effects connected with the meson decay.

It was found that the cosmic ray intensity at sea level shows a correlation with atmospheric temperature. This seemingly strange phenomenon was interpreted by Blackett in the following way. If the temperature of the atmosphere rises without change of pressure the atmosphere expands and the layers in which the mesons are formed will move upwards. Thus the mesons produced during a period of high atmospheric temperature are formed higher than those produced during a period of low temperature and therefore a larger fraction is expected to decay before reaching sea level in a period of high temperature than during a period of low temperature. Thus the cosmic ray intensity is expected to vary inversely with the temperature. It was found that the intensity decreases by 0.2 per cent. for a temperature increase of 1°C. This effect can be accounted for quantitatively using the equation (5) for the average path length of the meson.

The apparent mean life of the meson was also measured by comparing the absorption of mesons in atmospheric air with the absorption in dense materials. The experimental procedure is roughly as follows. The intensity of mesons with momentum P is measured (a) at sea-level; (b) at a height h above sea level under an absorber which is mass equivalent to the layer of air between sea level and the height h. The intensity of the mesons as measured under (a) and under (b) would be the same if the mesons were stable as in both cases the mesons have to penetrate the same absorbing mass. Because of their instability, however, some mesons which can reach the arrangement at the high altitude h will not reach sea level but decay on their way. Thus the ratio of the intensities observed at sea level and at the height h under the absorber can be used to determine the apparent life time t'_o. Experiments of this kind were carried out and they confirm the relativistic relation (5).

The confirmation of the relativistic time contraction by observations of the meson is of interest because it is confirmed in a region where the relativistic effect is not a small correction but gives rise to a large factor.

The following question might arise in connexion with the relativistic time contraction. An observer travelling with the meson will observe the half life of the meson to be t_o. How can this observer account for the fact that the meson is able to penetrate during the short time t_o the 16 km. from the height where the mesons are formed down to sea level? The answer is that the observer travelling with the meson finds that the atmosphere is moving with the velocity v and he finds, therefore, that the atmosphere had contracted in a ratio

$1 : (1-v^2/c^2)^{1/2}$

Thus the moving observer finds the life of the meson equal to t_o but finds that the atmosphere has contracted sufficiently to make the passage in the short time possible.

The Formation of the Meson

Because of their instability mesons cannot be assumed to come from outside space but must be produced by a primary radiation falling on the atmosphere.

From the study of the geo-magnetic distribution of the cosmic ray intensity it has been deduced that most of the primaries giving rise to the mesons are positively charged. It is assumed that these primaries are protons.

The protons falling on the atmosphere are believed to disappear quickly after having created mesons. The range of the primary protons cannot be long as otherwise they would frequently penetrate deep into the atmosphere producing there more mesons. Observations have shown that the rate of production of mesons at low altitudes is very small. Nevertheless, with special precautions the production of mesons can be observed even at sea level. The production of mesons may be attributed to the third component of cosmic rays mention further above. Fig. 8 represents a cloud chamber photograph showing three tracks coming from one point. These tracks are believed to be due to three mesons created in a point close above the cloud chamber.

(see p. 466 for Bibliography.)

Fig. 5. General View of High-Speed Sealing-in Machines—(B.T.-H. Co.).

The Technique of Glass Manipulation

Part 1.

By G. A. PERCIVAL. A.Inst.P.

TWENTY-FIVE years ago a glass-blower was considered skilled if he made a few hundred bulbs in an eight-hour shift. To-day, one Corning machine stamps out three hundred thousand bulbs in the same time, and of better quality.

In spite of such progress, "hand" methods of glass-blowing remain not only as a craft, but, as an industry, and between the extremes are semi-automatic methods of production where the craftsman and the engineer join forces in a compromise.

Electron tubes, lamps, laboratory apparatus and similar products all come within these two categories, and this article is an attempt to deal with the practical problems in manufacture so far as glass manipulation is concerned. Glass manufacture is a subject apart.

Precision machinery requires precision material. Variation in either composition or physical characteristics invariably causes trouble when a process is mechanical. The craftsman can make allowances for such things, but with a machine operating on an "index" of split seconds, material must be regular in all respects.

Glass for "lamp-working"—a generally accepted term derived from the early days when carbon-filament lamps were made by hand—may be anything from a refractory boro-silicate to a low-fusing lead glaze. Usually, for reasons of cost, it is based on a soda-lime formula in which, of course, silica predominates. Lead glass is no longer used to any appreciable extent in England and America, although it was popular on the Continent before the war. In any case, it is largely restricted to use as a "piecing" in lamp manufacture, in view of its low melting point which facilitates quick "tipping-off" after exhausting. For the same reason it is unsuitable for apparatus in which any great amount of heat is generated—as in transmitter valves—unless it also contains a considerable quantity of potash.

The term "melting point" is used with regard to glass, as indicative of the temperature at which it becomes plastic. Glass has no true melting point: it merely becomes less viscous with increasing heat; but different glasses vary in their viscosity over a given range of temperature, a property which determines the index of assembly on a machine and the setting of the "fires" or "blow-pipes."

The difference between lead and soda-glass is just as obvious in hand-working. Soda-glass takes up a positive set more quickly, not that this is any criterion of quality, for it may be little more than a water-soluble silicate if the alkali content is in excess. Such glasses fuse at a low temperature, but devitrify and have no durability. For this reason, glass for laboratory and industrial work must be selected with a view to its ultimate use.

It would be bad selection to make laboratory ware with an alkaline glass when chemical reactions are involved. Neither would it be consistent to use a soft lead-glass for apparatus involving direct current. Even the craftsman is limited by the nature of material; but he has the advantage of flexibility in manipulation.

Grading of Glass

In mechanical assembly, grading and sorting of material is as important as composition. If fires are set to melt a 2 mm. rod in five seconds, a 3 mm. rod would be under-melted, and a 1 mm. rod over-melted, in the same time. Tolerances there must be, as in all engineering processes, and the efficiency of valve manufacture is largely dependent upon the degree of regularity in grading rod, tube and bulbs.

Mixed sizes cause as much confusion as do glasses of different compositions, just as would 5 in. shells if supplied for 7 in. guns. Therefore, accurate grading in the initial stages of manufacture is economical. Not that it need be of that order determined only by means of a micrometer or in terms of milligrams, and usually the supplier does most of the work; but with hard-drawn tube in particular, there is always a considerable variation in diameter and wall thickness, and though machine-drawn tube is more regular, the same applies. In view of this the valve engineer has to decide on the relative efficiency in terms of production, speed, and loss. Tolerances must decrease as the machine speed increases; but material unsuitable for use on a high-speed machine can be used economically on hand, or semi-automatic machines where the operator controls the speed.

In making large valves and certain parts for discharge tubes this soon becomes obvious. It is not so much a question of loss in the first operation which counts, as loss after complete assembly. A stem (or "foot") represents only a fraction of a penny, but if a stem cracks after a valve has been exhausted and is ready for testing, the value has increased several times. The cumulative effect of this is somewhat staggering, even in the best organised factory, and from an industrial point of view, elimination of errors in the initial stage more than compensate for a post-mortem of purely technical interest.

Table I, giving standard sizes of tubing and rod, shows the limits within which the manufacturer works, but even on this basis, in a length of 46 in., the diameter at each end may be different, and the larger diameter determines the gauge. This applies to all glass which goes to make a stem, so that in total there may be a difference of 3 mm., apart from questions of wall thickness in the tube.

The engineer knows that with his machine, operations will be repeated exactly, so long as the material used is regular. He can set his fires for thin or thick glass, but not for both together. Accurate grading is, therefore, a basic principle in the mechanical manipulation of glass, and is usually dealt with as follows:—

Tube—small for exhaust connexions and large for stems—is gauged, and weighed to determine the wall thickness.

Rod (or "cane") is sorted according to diameter with "go" and "no-go" gauges.

Most bulbs are regular in external dimensions, but often vary in thickness, the top—or round part—being heavy by comparison with the neck which ultimately is joined to the flange. Glass thickness of a curved surface can only be measured satisfactorily with special instruments. Weighing is a useful check, but no guarantee of regularity.

TABLE I.
Standard Sizes of Glass Rod and Tube.

Gauge No.	Metric Diameter Millimetres Min.	Max.	English Diameter Inches Min.	Max.
1	1.000	1.072	.0395	.0422
2	1.072	1.149	.0422	.0452
3	1.149	1.231	.0452	.0485
4	1.231	1.320	.0485	.0520
5	1.320	1.414	.0520	.0557
6	1.414	1.516	.0557	.0597
7	1.516	1.624	.0597	.0640
8	1.624	1.741	.0640	.0686
9	1.741	1.866	.0686	.0735
10	1.866	2.000	.0735	.0787
11	2.000	2.144	.0787	.0844
12	2.144	2.297	.0844	.0905
13	2.297	2.462	.0905	.0969
14	2.462	2.639	.0969	.1039
15	2.639	2.828	.1039	.1114
16	2.828	3.031	.1114	.1194
17	3.031	3.249	.1194	.1279
18	3.249	3.482	.1279	.1371
19	3.482	3.732	.1371	.1469
20	3.732	4.000	.1469	.1575
21	4.000	4.287	.1575	.1688
22	4.287	4.595	.1688	.1809
23	4.595	4.925	.1809	.1939
24	4.925	5.278	.1939	.2078
25	5.278	5.657	.2078	.2227
26	5.657	6.063	.2227	.2387
27	6.063	6.498	.2387	.2558
28	6.498	6.964	.2558	.2742
29	6.964	7.464	.2742	.2939
30	7.464	8.000	.2939	.3150
31	8.000	8.574	.3150	.3376
32	8.574	9.190	.3376	.3618
33	9.190	9.849	.3618	.3878
34	9.849	10.556	.3878	.4156
35	10.556	11.314	.4156	.4454
36	11.314	12.126	.4454	.4774
37	12.126	12.996	.4774	.5117
38	12.996	13.929	.5117	.5484
39	13.929	14.928	.5484	.5877
40	14.928	16.000	.5877	.6299
41	16.000	17.148	.6299	.6751
42	17.148	18.379	.6751	.7236
43	18.379	19.698	.7236	.7755
44	19.698	21.112	.7755	.8312
45	21.112	22.627	.8312	.8908
46	22.627	24.251	.8908	.9548
47	24.251	25.992	.9548	1.0233
48	25.992	27.858	1.0233	1.0968
49	27.858	29.857	1.0968	1.1754
50	29.857	32.000	1.1754	1.2599

Glass Stems

A stem is the foundation upon which most valves are built. In nearly every type of stem a flange is used. With valves, the exhaust tube may be sealed in the flange or joined to some other part of the bulb. With lamps, a rod and exhaust tube are sealed together with a flange to form a stem; but a valve stem has no rod, as most of the internal construction is fixed to electrodes—or "leading-in" wires—and metal supports imbedded in the stem. The flange is, therefore, a vital part of the completed article.

It is made by one of two methods, (a) cutting tube into lengths and then flanging or (b) flanging the end of a long length and then cutting the length of tube required by means of a needle flame.

Method (a) may be a hand or automatic operation. Method (b) is entirely automatic, one machine being capable of producing 1,200 flanges an hour, with one operator attending six or more machines.

Cutting glass tube or rod is not so simple as might be expected, and several methods are adopted though all are fundamentally the same. Most laboratory workers have had occasion to "cut" glass with a file, not always with the best result. The professional glass-blower uses a hard steel knife. Industrially, a carborundum wheel (Fig. 1) is used for small tube and rod, and a hot wire—or hot glass and a cold stone—for larger sizes. Tube of anything above 4 in. in diameter is preferably cut under water with a "wet stone."

Whatever method is adopted, some breakage is inevitable; a good deal can be avoided.

Cutting Tube

Whether in transport or handling, for every length of glass broken an

Fig. 1. Cutting glass tube on a carborundum wheel.

additional squaring up of ends is necessary. All this causes loss. When packed for transport, every break scatters tiny splinters which scratch the remaining glass, the fragility of which depends on quality and packing. The result of this is not at once apparent, but immediately cutting is attempted, the strains develop into cracks.

Transport breakage, apart from carelessness, is often indicative of bad quality or extremely hard glass. Sudden heating or even a knock may cause it to shatter. The only remedy for such things is careful visual inspection and to buy from a reputable manufacturer. One must be careful, however, not to blame the manufacturer when one's own technique is at fault.

Chipping, for example, is usually due to wrong direction in cutting. To avoid waste in squaring ends, an operator will often cut too close to the end and only start a second chip. This may be repeated several times before a smooth end is obtained. Obviously, the remedy is to have an experienced operator on the squaring, leaving the routine cutting to others.

Cracks are distinct from chips. Each is what the term implies. Subject to reasonable quality of glass, cracks are caused by wrong manipulative treatment, either on the part of the operator or because of wrong adjustment on a machine. Every laboratory worker finds a tendency to scratch and *bend* tube until it breaks, instead of pulling it apart, when, with a fine scratch, a clean edge will result. A coarse scratch gives the reverse effect, which is accentuated by bending.

The same applies on a commercial scale when using carborundum wheels, which is only a different way of scratching. If the glass is forced hard against the wheel, cracks will develop, partly from the heat suddenly generated. Similarly, if the wheel has not been trimmed to a sharp angle, or is running "out of true," or if it is running too slowly, a similar effect is produced. With small rod and tube a fine scratch is sufficient, and a girl will cut half a dozen pieces at a time by drawing them over a hard steel knife and giving a sharp pull. As the diameter increases, so the length, but not the width, of scratch should be increased.

Splitting differs from chipping or cracking—in a technical sense at any rate—in so much that a split occurs in a longitudinal direction. It is a defect largely confined to tube, (a) of uneven wall thickness, (b) with ridges, (c) of a hard or badly annealed glass, (d) which after cutting has been allowed to fall on a hard surface.

To prevent splitting, a craftsman always fire-polishes every raw edge. That, as already mentioned, is one advantage of the hot-cut flange machine; sharp edges are never formed. However, like most high-speed equipment, accurate adjustment is essential. Speed alone does not compensate for loss through breakage, and as each size of flange necessitates some alteration in fire-setting or timing, the best efficiency is obtained by keeping one machine permanently on one type of work. Where flexibility is required, it is better to use that type of machine in which the tubing is cut before flanging. Whatever method is adopted there are certain difficulties which are common to any process in which glass is melted as a preliminary to shaping.

Flange Making

The simplest machine for making flanges is that in which four revolving chucks are mounted on a revolving head, as shown in Fig. 2. The chuck at the bottom is in neutral gear, so that the operator can insert a length of tube before the head carries it to the front position where it becomes slightly warmed. At the top, the fires play on the free end of the tube until it melts, or perhaps it would be better to say, "softens." When in this condition, the operator inserts a carbon rod or a carbon-coated "reamer" and splays the glass out to the proper angle. The flange, now formed, passes away to the back while another is being made. As each loaded chuck reaches the bottom, the flange is ejected and a fresh piece of glass inserted, so that at all times, except for that brief moment of ejecting and reloading, the machine is full. Production is about 300 an hour with a flexibility enabling a wide range of flanges to be made without any mechanical changes.

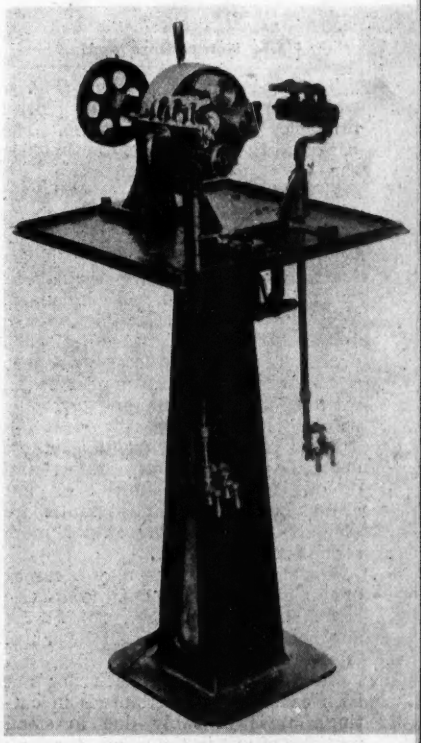


Fig. 2. Semi-automatic Flange Machine.

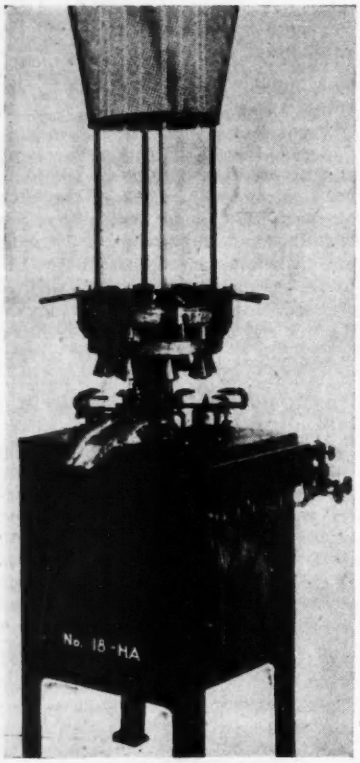


Fig. 3. Hot-cut flange machine.

The hot-cut flange machine (Fig. 3. while working on the same general principle, is quite automatic. The basket at the top is merely for holding the eight (or more) lengths of tube steady as the main table revolves. The length of tubing set in each chuck is about 48 in., the length projecting being controlled by a stop. Each chuck rotates so that the end of the tube is progressively warmed, melted, flanged, annealed and cut off, leaving a fresh section of tubing at the end of each cycle. The completed flange falls into a conveyor, is further annealed and carried forward to the proper assembly point.

From a brief description, these operations may appear simple and direct. In practice this does not always follow, and unless faults are diagnosed in the early stages more serious troubles follow.

With flanges, cracks may occur at one or all of three places. (a) In the barrel, or straight part. (b) At the angle between the barrel and the flange. (c) In the flange proper.

Assuming that the crack has not been caused (and overlooked) in cutting, (a) is probably due to small particles of grit in the chuck, the jaws of which must be smooth, and adjusted to grip lightly but firmly. Undue pressure will cause cracks. Any tendency to slip will cause scratches which will develop into cracks. The most critical factor, however, is in the setting of the fires. Too much heat will cause the glass to run; too little will make working difficult, and introduce strains which cause (b). If the glass runs, it is always liable to form a rim on the circumference of the flange and most of the troubles under (c) can be attributed to this; but as there is always a slight variation in the temperature of melting, due to differences in the thickness of the glass, and draughts blowing the fires about, cracked flanges may result from improper annealing. This is particularly so with hand-operated flanging machines.

Bad shapes are primarily due to irregular glass. If tubing is elliptical, or thicker on one side than on the other, no ordinary manipulation can make a perfectly regular flange. Provided the difference is not too great it is of little importance except where equally bad bulbs have to be used, but together they must obviously cause a certain amount of loss. Under those conditions it is better to use a *good* bulb with a *bad* flange than a good flange with a bad bulb. The shrinkage is less.

The size of a flange has a definite relationship with the neck diameter and thickness of the bulb into which it will be sealed. Too small a flange necessitates excessive "pull-down" in sealing. A large flange, on the other hand, will form a seal too large to fit into the valve base—or lamp cap. Wrong sizes in flanges are due to, (a) under or over-melting the tube in flanging, (b) wrong setting of fires or timing; irregular "reaming" on hand-operated machines.

Stem Making

Without some knowledge of the processes just described, it is difficult to understand the next operation of stem-making, in which the straight part of the flange is joined to electrodes (or leading-in wires) with an exhaust tube, and metal support wires for valves, or glass rod for lamps. The design of a stem may vary enormously and have anything from one to eight wires, but for reasons of brevity, consider the ordinary valve stem.

Since the method of assembly is an excellent example of mechanised craftsmanship, it is of equal interest to both laboratory worker and factory engineer, combining as it does the essentials of glass manipulation and engineering skill.

A stem machine may have as few as one head or as many as forty-eight, but the basic principle is the same. With a multiple machine the "stem heads" are mounted on a circular table which revolves. The stem heads may or may not revolve as individual units. This is largely a question of preference, and with the large high-speed machines the heads are stationary. In any case the process is the same, though the speed and output are different, and may be likened to a round conveyor belt on which the operator places the parts to be assembled, and after a complete cycle, takes them off again as a unit.

Fig. 4 is a close-up of a stem in a 24-head machine immediately before being "pinched" or melted, as is seen on the left-hand side. The pinch is the point at which all the parts are sealed together to make a vacuum-tight joint. As the stem head moves to the next position, warm air is blown down the exhaust tube while a needle flame plays on that part of the stem where it is joined in the pinch. Immediately this small, local area becomes soft the glass is blown into a bubble by the air pressure which is continued until the bubble bursts and leaves a hole about 2 mm. in diameter. All this, of course, is automatic in operation as is the fire-polishing of the hole after it has been made.

With a high-speed machine, a general view of which is shown in Fig. 5, the stem is formed slowly and progressively as distinct from the more "jerky" operation of an 8-head machine in which treatment of the glass is rather more severe; yet all stem machines give very much the same troubles—so far as the product is concerned.

Considering stems of the so-called "standard" manufacture, experience shows that breakage and faults come within four main groups, *viz.*, cracked pinches; cracks between the exhaust tube and pinch; broken exhaust tubes.

Stem Breakage

Any strain introduced as the result of bad cutting or flanging is liable to develop into a crack when the glass is suddenly heated, and if the annealing has been insufficient, the cracks will show at stem making. The same strains may be introduced during stem making, for in all types of machine the flange is held between the jaws which grip the straight, tubular, part and leave the flange proper outside the area of direct heating. Unless the stem-jaws are mechanically true with the centre of the "stem-block" which holds the electrodes in correct relation to the inside of the flange, there will be a slight cant of the glass, and any vibration will cause scratches. This condition is aggravated when an

operator on a hand machine allows the jaws to snap together, and if particles of grit or broken glass have become imbedded in the jaws, a stem is ruined before it is finished.

With complex stems in which there are several electrodes and as many support wires, conditions arise in which strains develop after annealing. It may be due to physical differences between the component parts or to large joints in the electrodes, which are a composite of three wires with two welds, both of which are actually in the pinch. In the same way, support wires imbedded in the stem too far, will cause cracks, hours, or even days after completion.

Measuring a cracked pinch may often serve as a useful means of checking the alignment of the stem-jaws which should be parallel in a horizontal plane, but at a slight angle in the vertical, so that molten glass is squeezed on to the wires in such a way that air bubbles are removed. From measurements like this it is often possible to identify the particular stem-head which is giving trouble. Even after correct setting, regular inspection should be made, for under conditions of extreme heat, mechanical wear, and corrosion, irregularities develop unnoticed. Painting all parts with graphite reduces this tendency and saves adjustments.

Apart from such precautions, a machine may run satisfactorily for a long time, but in manipulating a difficult substance, unless all variables are reduced to a minimum, efficiency will suffer. Normal breakage is due to the cumulative effect of a number of differences, each in its way being insignificant. Excessive breakage arises from some prime cause, such as too wide a latitude in the specification of raw material, for which reason mechanical precision in assembly is all the more important.

Irregular breakage is probably due to irregular material. A steady increase in breakage is more likely to be due to wrong setting of the fires. Over melting gives a lumpy, uneven stem. A "cold pinch" is characterised by sharp corners. Badly shaped stem jaws give a similar appearance and result.

In all types of stem machine a small jet of air is directed into the well of the stem to prevent the wall of the tube from flattening. Without this the glass would thicken; but if, on the other hand, the air jet is too fierce, strains will be introduced, but not necessarily removed by the ordinary annealing. Cracks from this cause are very easily distinguished, and remedied.

It is not always necessary, or even desirable, that exhaust tube should be of the same composition as the flange tube. In lamp manufacture, as already mentioned, there is a certain advantage in having a soft, quick melting glass which can be sealed off on the exhausting machine; but size is a factor which may make the difference of five per cent. in loss. If the exhaust tube is made of too hard a glass it may be pinched into the stem without being actually melted, and if all the parts are not fused together in the first instance, the tube will crack where it joins the pinch, or the pinch will crack. The same effect is produced if the exhaust tube is out of centre, and for similar reasons.

Annealing

It is not strain, but unequal strain, which causes breakage. Properly controlled and distributed strain is often introduced to prevent breakage. When unequal or great, it must be equalised by heat treatment suited to the particular conditions. The actual "annealing range" of any glass lies within narrow limits, of which only the top temperature can be determined with any accuracy. Known as the "strain point," it is that temperature from which a piece of glass can be quickly cooled without introducing permanent strains. An ordinary soda-potash-lead glass has an annealing point of 431°C. The strain point is 395°C.* Therefore, the annealing range is between these two limits.

If stems made from this glass were annealed below 395°C., the effect would be negative. On the other hand, no useful purpose would be served by annealing above 431°C. In fact, considerable harm might result if the exhaust tube in the stem became so plastic as to fall out of centre. Neither must the influence of dimensions be forgotten. The time taken for annealing a miniature stem will not be the same as that required for a large valve, even if the glass were the same composition in both cases. For this reason it is useful to determine the time-temperature factor for annealing any standard unit in manufacture. This applies more particularly to semi-automatic machines where the annealing apparatus is gravity fed or independently driven, as distinct from high-speed machines where an annealing conveyor is geared to the mechanism to give a positive time schedule.

Table 2 gives the approximate annealing temperature for several types of glass as used in lamp and valve manufacture. As already mentioned, however, the time factor must always be considered. Pyrex, for instance, can be annealed at 430°C., but it takes two years.†

TABLE II

Type of Glass	Annealing Point °C.
Lead	425
Soda-Lime	510
Monax	522
Pyrex	550
Quartz	1,120

(*To be continued*)

* Littleton, *J. Am., Ceram. Soc.*, 19, 243 (1936).

† Morey and Warren, *Ind. Eng. Chem.*, 27, 966 1935.

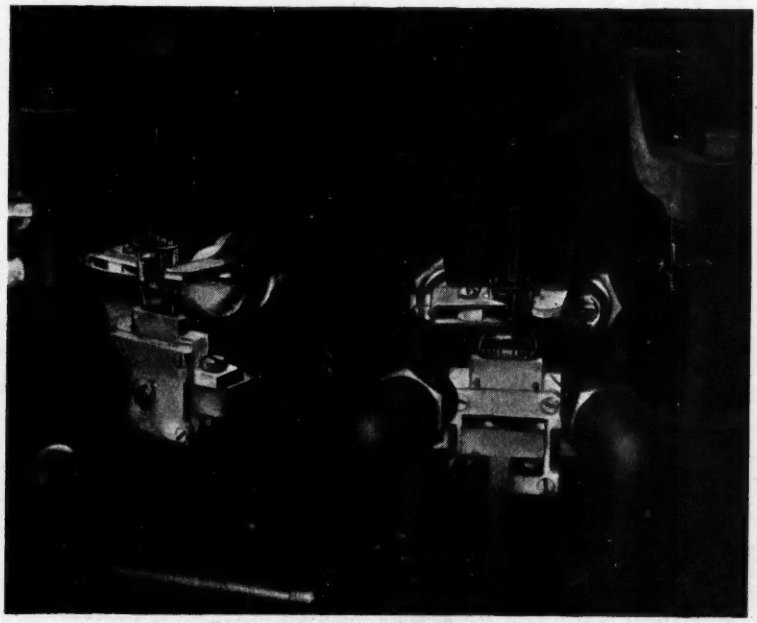


Fig. 4. Close-up of stem-making machine.

"The Golden Arrow"

The British Army's Latest Mobile Wireless Station

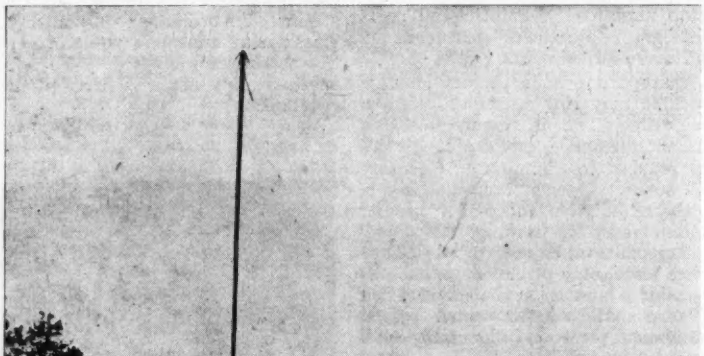
THE Royal Signals Wireless Station "Golden Arrow" is virtually a mobile adaptation of the normal type of small fixed commercial radio-telegraph station and, while providing the traffic-handling capacity of such a station, is fully mobile and can be set up or dismantled in three or four hours.

The complexity and bulk of the station necessarily restricts its use to the main arteries of communication such as those between Army H.Q. and G.H.Q. or between a mobile G.H.Q. overseas and a fixed station in the U.K. Fortunately it is only on such a main artery that the amount of traffic rises to figures that cannot be disposed of without resource to automatic working.

The "Golden Arrow" and its crew of 22 is completely self-contained and carries its own collapsible mast gear, spare valves, power supply and administrative stores. The cook with his portable petrol cooker is naturally a most important member of this little community.

As far as possible the equipment has been rendered capable of operating in any climate from subarctic to tropical. This has already proved of great value as sets are now in service in places as far apart as Italy and Bengal.

The first "Golden Arrow" in Sicily went ashore late one evening



Receiving van and aerials. The upper photograph shows the complete 'train' of vehicles on the road.

Inside the receiving van, showing the communication receivers and perforators.

Changing taps on the transmitter. (*Fox Photos.*)

from a landing craft. By 9 o'clock next morning it was hard at work carrying messages to and from the War Office, 1,200 miles away. The erection of a fixed station of this type, involving the design and erection of a number of buildings, would, under peace-time conditions, take six to twelve months.

Transmitter

The transmitter itself is carried in a large semi-articulated vehicle and is of about 3 kW aerial rating. The transmitter is on the left when entering the side door and spare coils are stored in a rack against the near-side wall. The anodes of the high-power valves are cooled by a blast of air from a blower.

Facing the transmitter is the cubicle which contains the main transformers and mercury vapour rectifiers for supplying power, and the overload and time-delay relays which protect the transmitter from damage due to faults or incorrect operation.

Behind the power supply cubicle there is a special resilient stowage for the carriage of spare power valves.

The aerial gear is all carried in or on the vehicle (the mast sections are slung below the trailer chassis) and when erected provides two dipoles on 70-foot masts—one being used for the day (high) frequency, and the other for the night, or lower frequency.

Receiving Vehicle

The receiving vehicle is of similar shape to the transmitter vehicle, but contains a very complicated installation as it forms the traffic office in which the majority of the crew work. The forward end of the vehicle is divided off and contains an air-conditioning equipment which supplies a current of cool dry air to the operating room through a duct slung below the ceiling. As the air intakes to this plant are covered with filters the interior of the vehicle is kept free of dust, sand and (last but by no means least) of flies and mosquitoes. In order to assist in keeping the vehicle interior cool, the "skin" of the vehicle and the floor is "lagged" with glass wool. Not only does this air-conditioning prevent the unbearable conditions otherwise inevitable in a small crowded vehicle standing in a tropical sun, but the exclusion of sand reduces the wear on the delicate instruments within.

In cold climates a 3kW heating element in the air intake replaces the cooling compressor, and the vehicle is consequently ventilated and warmed in a pleasant manner.

The vehicle contains a long operating bench on the off-side, which carries (from right to left) two keyboard perforators, a receiving undulator, a Wheatstone transmitter hand key, and a spare undulator. The radio receivers themselves, which are high-grade communication receivers are carried on resilient mountings on a shelf above the undulators, together with a "Recording Bridge" which converts the interrupted audio-frequency note from the receiver into direct current to operate the undulator.

The receiving aerials are similar to those for the transmitter except that a coaxial feeder is employed between the dipole itself and the receiver.

Tracking in Superheterodyne Receivers

Part II – Conclusion

By S. W. AMOS, B.Sc., (Hons).

Padder Method

ANOTHER, and in some respects better method of securing two point tracking is that illustrated in Fig. 5, in which it will be noted that a padding condenser, C_p, has been placed in series with the oscillator tuning condenser. Proceeding as in Part I, we have, as before :—

$$\frac{C_1}{C_2} = \left(\frac{\omega_2}{\omega_1}\right)^2 \quad \ldots\ldots (6)$$

$$\frac{C_1C_p}{C_1+C_p} \cdot \frac{C_2+C_p}{C_2C_p} = \left(\frac{\omega_2+\omega'}{\omega_1+\omega'}\right)^2 \quad \ldots\ldots (7)$$

From (7)—

$$\frac{C_2+C_p}{C_1+C_p} = \left(\frac{\omega_1}{\omega_2} \cdot \frac{\omega_2+\omega'}{\omega_1+\omega'}\right)^2$$

giving—

$$C_p = \frac{1}{\omega'^2 L_s} \cdot \frac{a+b}{a\omega_1+b\omega_2} \quad \ldots\ldots (8)$$

where, as before,

$a=\omega_2+\omega'$ and $b=\omega_1+\omega'$.

Knowing C_p we can obtain L_{osc} from the relationship—

$$L_{osc} = \frac{C_1 + C_p}{(\omega_1 + \omega')^2 C_p C_1}$$

where $C_1 = \dfrac{1}{\omega_1^2 L_s}$

The values of C_p and L_{osc} for use on the long, medium and short wavebands are given in Table IV. The tracking results obtained with these values of components are exhibited in tabular form in Tables V, VI and VII and in graphical form in Fig. 6 (which should be compared with Fig. 2) and Fig. 7 (which should be compared with Fig. 4). These comparisons show quite plainly the superiority of this circuit over that analysed in Part I. Not only is there less loss due to tracking error in this circuit, but also there is a superior performance with respect to second channel rejection on short waves. Notice, however, the large value of C_p required on short waves. It is difficult to manufacture a variable condenser of value .00405 $\mu\mu$F—and it would need to be variable to give perfect alignment. It is much easier to provide a variable condenser of, say, 30$\mu\mu$F, which would enable the corresponding value of C_t of 7.81 $\mu\mu$F to be obtained. This is probably why the "trimmer" circuit is preferred by manufacturers, despite the superior performance of the other.

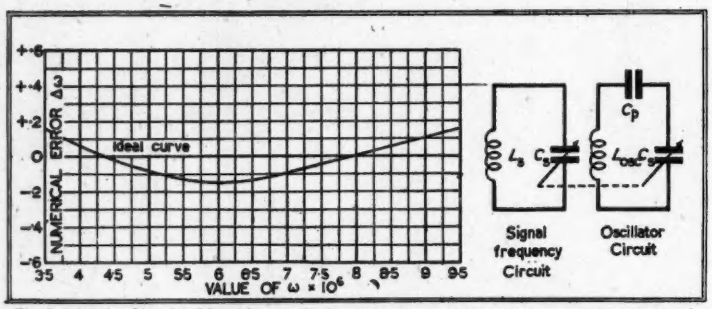


Fig. 5. (right) Circuit of 'padder method' of tracking and (Fig. 6.) the tracking obtained.

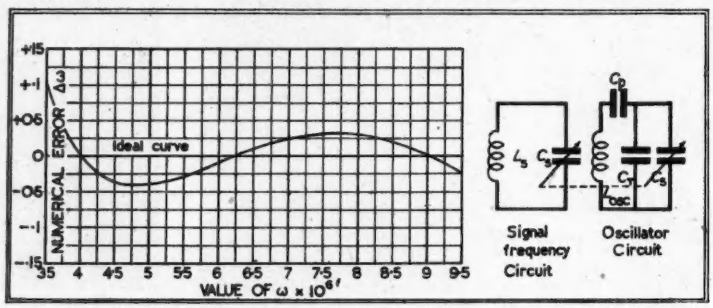


Fig. 8. (right) Circuit of 'three-point' method and (Fig. 9.) the tracking obtained.

Although it is not shown in the circuit of Fig. 5, it is necessary even with the padder circuit, to include a trimmer to equalise the capacitance of the two sections of the ganged tuning condenser assembly. By the inclusion of a trimmer one introduces a third variable into the oscillator circuit, thereby making perfect tracking possible at three frequencies in each band, in which case an even superior performance is possible. We find, therefore, that this "padder" method is rarely used in practice, whilst three point tracking is extensively used in long and medium wave circuits.

Analysis of Three Point Tracking

Possibly the commonest circuit for three point tracking is as given in Fig. 8. We will assume that perfect tracking is wanted at the three frequencies which correspond to ω_1, ω_2 and ω_3, where $\omega_3 > \omega_2$ and $\omega_2 > \omega_1$. For the signal frequency circuit, we have, with the same notation as before—

$$\omega_1^2 = \frac{1}{L_s C_1} \quad \ldots\ldots (9)$$

$$\omega_2^2 = \frac{1}{L_s C_2} \quad \ldots\ldots (10)$$

and

$$\omega_3^2 = \frac{1}{L_s C_3} \quad \ldots\ldots (11)$$

As the ganged condenser assembly consists of identical sections, C_1, C_2 and C_3 will also be the capacitances of the oscillator section. However, the effective capacitances corresponding to signal angular frequencies of ω_1, ω_2 and ω_3 will be respectively C_1', C_2' and C_3', where—

$$C_1' = \frac{(C_1+C_t)C_p}{C_1+C_t+C_p} \quad \ldots\ldots (12)$$

$$C_2' = \frac{(C_2+C_t)C_p}{C_2+C_t+C_p} \quad \ldots\ldots (13)$$

and $C_3' = \dfrac{(C_3+C_t)C_p}{C_3+C_t+C_p}$ ..... (14)

When the signal frequency circuit is tuned to a frequency of $\omega_1/2\pi$ the oscillator circuit must, for perfect tracking, be tuned to a frequency of $\dfrac{\omega_1+\omega'}{2\pi}$. Similar results apply for signal frequencies of $\omega_2/2\pi$ and $\omega_3/2\pi$ so that we have—

$$(\omega_1+\omega')^2 = \frac{1}{L_{osc}C_1'} \quad \ldots\ldots (15)$$

$$(\omega_2+\omega')^2 = \frac{1}{L_{osc}C_2'} \quad \ldots\ldots\ldots (16)$$

and $$(\omega_3+\omega')^2 = \frac{1}{L_{osc}C_3'} \quad \ldots\ldots\ldots (17)$$

Dividing (15) by (16)—

$$\left(\frac{\omega_1+\omega'}{\omega_2+\omega'}\right)^2 = \frac{C_2'}{C_1'}$$

Substituting for C_2' and C_1' from (12) and (13) respectively—

$$\frac{C_2+C_t}{C_2+C_t+C_p}\cdot\frac{C_1+C_t+C_p}{C_1+C_t} = \left(\frac{\omega_1+\omega'}{\omega_2+\omega'}\right)^2$$

from which, writing x for $\left(\frac{\omega_1+\omega'}{\omega_2+\omega'}\right)$, we have:

$$C_p = \frac{x-1}{\frac{1}{C_1+C_t} - \frac{x}{C_2+C_t}} \quad \ldots\ldots\ldots (18)$$

To simplify the algebra, which is very easily apt to become very awkward and cumbersome in analyses of three point tracking, we shall now assume that—

$$\frac{\omega_1+\omega'}{\omega_2+\omega'} = \frac{\omega_2+\omega'}{\omega_3+\omega'}$$

The exact physical significance of this step is that once ω_1 and ω_2 have been chosen, ω_3 is automatically fixed by the relationship—

$$\omega_3 = \sqrt{(\omega_1+\omega')\ (\omega_2+\omega')} - \omega' \quad \ldots\ldots\ldots (19)$$

Thus although perfect tracking will be obtained at three points in the wave-band, only two can be chosen arbitrarily. Suppose, in a medium wave tracking circuit, we decide that ω_1 shall be 4×10^6 and ω_2, 9×10^6, ω' as before, being 3×10^6. We have, from (19)—

$$\omega_3 = \sqrt{7\times12\times10^6} - 3\times10^6 = 6.165\times10^6$$

Tracking will be perfect, therefore, at $\omega = 4\times10^6$, 6.165×10^6 and 9×10^6. If ω_1 and ω_3 are the opposite extremes of a wave-band, therefore, ω_2 will be close to the middle of it, so that this simplifying assumption is no drawback.

Dividing (16) by (17) and substituting for C_2' and C_3' from (13) and (14) respectively we have—

$$\frac{C_2+C_t}{C_3+C_t+C_p}\cdot\frac{C_2+C_t+C_p}{C_2+C_t} = \left(\frac{\omega_2+\omega'}{\omega_3+\omega'}\right)^2$$

Solving this for C_p we have—

$$C_p = \frac{x-1}{\frac{1}{C_2+C_t} - \frac{x}{C_3+C_t}}, \quad \ldots\ldots\ldots (20)$$

which corresponds exactly with (18).

Equating (18) and (20) and solving the resulting equation for C_t it may be shown—

TABLE IV

Values of padding condenser and oscillator inductance for the three wavebands.

	Long Waves	Medium Waves	Short Waves
Lower frequency limit	$\omega = .95\times10^6$ rads./sec.	$\omega = 3.5\times10^6$ rads./sec.	$\omega = 37\times10^6$ rads./sec.
Upper frequency limit	$\omega = 1.9\times10^6$ rads./sec.	$\omega = 9.5\times10^6$ rads./sec.	$\omega = 113\times10^6$ rads./sec.
Lower alignment frequency	$\omega_1 = 1.2\times10^6$ rads./sec.	$\omega_1 = 4.5\times10^6$ rads./sec.	$\omega_1 = 40\times10^6$ rads./sec.
Upper alignment frequency	$\omega_2 = 1.65\times10^6$ rads./sec.	$\omega_2 = 8.0\times10^6$ rads./sec.	$\omega_2 = 100\times10^6$ rads./sec.
Value of padding capacitance	107.7 $\mu\mu$F	357 $\mu\mu$F	4050 $\mu\mu$F
Value of oscillator inductance	706.2μH	106.2 μH	1.351 μH

TABLE V

Tracking obtained with the values of Table IV.—Medium Waveband.

Value of ω ($\times10^6$ rads./sec.)	Value of $\frac{\omega}{\omega_1}$	Value of Cs ($\mu\mu$F)	Value of Cosc ($\mu\mu$F)	Value of ωosc ($\times10^6$ rads./sec.)	Value of ωosc$-\omega$ ($\times10^6$ rads./sec.)	Value of $\triangle\omega$ ($\times10^6$ rads./sec.)	Value of $\delta\omega$ (per cent.)
3.5	.77	520	212	6.67	3.17	+.17	+4.86
4.0	.90	398	188	7.07	3.07	+.07	+1.77
4.5(ω_1)	1.00	315	167	7.50	3.00	0	0
5.0	1.11	255	149	7.96	2.96	−.04	−.86
5.5	1.22	211	132	8.43	2.93	−.07	−1.25
6.0	1.33	176	118	8.92	2.92	−.08	−1.40
7.0	1.55	130	95	9.94	2.94	−.06	−.86
8.0(ω_2)	1.77	99.5	71.7	11.00	3.00	0	0
9.0	2.00	78.6	64.4	12.10	3.10	+.10	+1.11
9.5	2.11	70.6	58.9	12.63	3.13	+.13	+1.37

TABLE VI

Tracking in Long Waveband—Padder Method.

Value of ω ($\times10^6$ rads./sec.)	Value of $\frac{\omega}{\omega_1}$	Value of Cs ($\mu\mu$F)	Value of Cosc ($\mu\mu$F)	Value of ωosc ($\times10^6$ rads./sec.)	Value of ωosc$-\omega$ ($\times10^6$ rads./sec.)	Value of $\triangle\omega$ ($\times10^6$ rads./sec.)	Value of $\delta\omega$ (per cent.)
1.00	.83	454	87.1	4.03	3.03	+.03	+3.3
1.20(ω_1)	1.00	316	80.3	4.20	3.00	0	0
1.30	1.08	269	76.9	4.29	2.99	−.01	−.7
1.40	1.17	232	73.5	4.39	2.99	−.01	−.86
1.50	1.25	202	70.2	4.49	2.99	−.01	−.57
1.65(ω_2)	1.37	167	65.5	4.65	3.00	0	0
1.75	1.46	148	62.4	4.76	3.01	+.01	+.74
1·90	1.58	126	58	4.94	3.04	+.04	+2.1

TABLE VII

Tracking in Short Waveband—Padder Method.

Value of ω ($\times10^6$ rads./sec.)	Value of $\frac{\omega}{\omega_1}$	Value of Cs ($\mu\mu$F)	Value of Cosc ($\mu\mu$F)	Value of ωosc ($\times10^6$ rads./sec.)	Value of ωosc$-\omega$ ($\times10^6$ rads./sec.)	Value of $\triangle\omega$ ($\times10^6$ rads./sec.)	Value of $\delta\omega$ per cent)	Second channel ratio (dbs.)
37	.925	519	460	40.12	3.12	+.12	+.325	−28
40(ω_1)	1.00	444	400	43.00	3.00	0	0	−29
50	1.25	284	266	52.78	2.78	−.22	−.44	−24.5
60	1.50	197	188	62.70	2.70	−.30	−.50	−22.5
70	1.75	145	140	72.72	2.72	−.28	−.40	−22
80	2.00	111	108	82.75	2.75	−.25	−.31	−22
90	2.25	87.7	85.8	92.86	2.86	−.14	−.16	−21.5
100(ω_2)	2.50	71.0	69.8	103.0	3.00	0	0	−21
120	3.00	49.3	48.8	123.2	3.20	+.2	+.17	−19.5

TABLE VIII

Tracking in Medium Waveband—3-point Method.

Value of ω ($\times10^6$ rads./sec.)	Value of Cs ($\mu\mu$F)	Value of Cosc ($\mu\mu$F)	Value of ωosc ($\times10^6$ rads./sec.)	Value of ωosc$-\omega$ ($\times10^6$ rads./sec.)	Value of $\triangle\omega$ ($\times10^6$ rads./sec.)	Value of $\delta\omega$ (per cent.)
3.5	520	265.1	6.536	3.036	+.036	+1.03
4.0	398.1	231.1	7.000	3.000	0	0
4.5	314.6	202.3	7.484	2.984	−.016	−.35
5.0	254.8	177.7	7.982	2.982	−.018	−.36
5.5	210.5	157.4	8.484	2.984	−.016	−.291
6.0	176.8	139.9	8.997	2.997	−.003	−.05
6.5	150.8	125.3	9.505	3.005	+.005	+.077
7.5	113.2	102.3	10.52	3.02	+.02	+.27
8.5	88.16	85.36	11.52	3.02	+.02	+.23
9.5	70.60	72.70	12.48	2.98	−.02	−.21

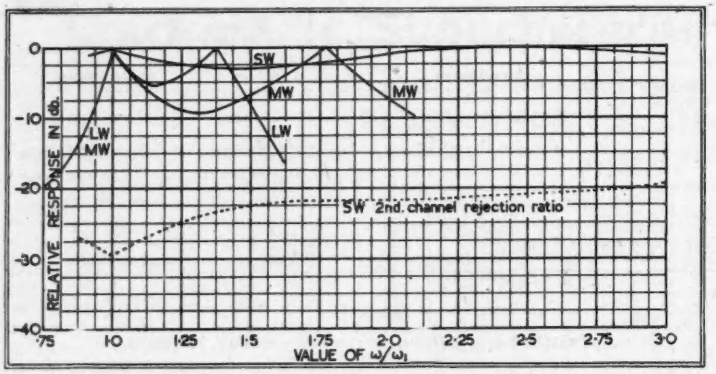


Fig. 7. Loss of sensitivity due to misalignment on the three wavebands—compare with Fig. 4 (part I).

$$C_t = \frac{C_3(C_2 - C_1) + xC_1(C_2 - C_3)}{C_1 - C_2 + x(C_3 - C_2)}$$

We can eliminate the unknowns C_1, C_2 and C_3 from this by substituting for them from (9), (10) and (11) respectively. We then have—

$$C_t = -\frac{1}{L_s} \cdot \frac{\omega_1^2 + x\omega_3^2 - \omega_2^2(x+1)}{\omega_2^2(\omega_3^2 + x\omega_1^2) - \omega_1^2\omega_3^2(x+1)} \quad \ldots\ldots\ldots\ldots (21)$$

from which, knowing ω_1, ω_3, L_s and x we can calculate C_t. ω_2 is obtained from (19).

C_p can be obtained from (18), by substituting for C_1 and C_2 from (9) and (10) respectively. We then have—

$$C_p' = \frac{x-1}{\frac{1}{\omega_1^2 L_s} - \frac{x}{\omega_2^2 L_s}} + C_t \quad \ldots\ldots (22)$$

Finally the value of L_{osc} may be obtained from (15), which may be rewritten thus, in which C_1' has been eliminated by substitution from (12)—

$$L_{osc}' = \frac{C_t + C_p + \frac{1}{\omega_1^2 L_s}}{(\omega_1 + \omega')^2 (C_t + \frac{1}{\omega_1^2 L_s}) C_p} \quad \ldots\ldots\ldots\ldots (23)$$

As an illustration of the use of these formulæ consider the medium wave-band. We have already shown by putting ω_1 equal to 4×10^6 and $\omega_3 = 9 \times 10^6$ we can achieve perfect tracking at $\omega_2 = 6.165 \times 10^6$ as well. Substituting these values, and $L_s = 157$ μH in (21) we find—

$$C_t = 13.7 \ \mu\mu F.$$

The value of x which was also required in (21) was evaluated as .583, from the relationship—

$$x = \frac{\omega_1 + \omega'}{\omega_3 + \omega'}$$

which is easily deduced from (19). Substituting the appropriate values in (22) and (23) gives us the results—

$$C_p' = 527 \ \mu\mu F.$$

and $L_{osc} = 88.3$ μH.

The performance of a medium wave tracking circuit in which $C_t = 13.7$ $\mu\mu$F, $C_p' = 527$ $\mu\mu$F and $L_{osc} = 88.3$ μH is set out in Table VIII and is also exhibited in graphical form in Fig. 9. This represents a great improvement over the performance of either the two point tracking circuits and reference to Fig. 3 will show that, apart from a small region at the low frequency end of the wave-band where the misalignment accounts for a loss of 7 db., the loss in sensitivity is everywhere less than 3 db.

It is convenient when designing long-wave oscillator circuits to let $\omega_1 = 1.00 \times 10^6$ and $\omega_3 = 1.85 \times 10^6$. If $\omega' = 3 \times 10^6$ then $\omega_2 = \sqrt{4 \times 4.85 \times 10^6 - 3 \times 10^6} = 1.404 \times 10^6$ and $x = \frac{4.00}{4.85} = .825$.

Substituting these values in (21), (22) and (23) gives the following results—

$$C_t = 48.8 \ \mu\mu F.$$

$$C_p' = 181.1 \ \mu\mu F$$

$$L_{osc}' = 467 \ \mu H.$$

Details of the performance of this long-wave oscillator circuit are not given; they are very similar indeed to those of the medium-wave circuit. It is noteworthy that for this long-wave circuit, as also for the medium wave one, the values of the trimming and padding capacitances are such that they can easily be made variable, *i.e.*, their values are about, or less than, 500$\mu\mu$F. This is not so for a three-point short-wave oscillator circuit. Simple comparisons will show that the values of C_p which apply for a simple two-point "padder" circuit are of the order of a half those required in a three-point tracking circuit. This means that C_p for a three-point circuit will be about .008 $\mu\mu$F, a value practically impossible for make variable.

The conclusions reached then are that three-point tracking is used on long and medium-wave circuits, where the tracking error can easily be kept below 1 per cent., which represents a negligible loss of sensitivity due to misalignment. Short-wave circuits generally are of the two-point "trimmer" type and this loss is somewhat greater but still permits a good performance.

NOTE :—*This subject is discussed fully in a forthcoming book*
"Radio Receivers and Transmitters"
by S. W. Amos and F. W. Kellaway
to be published by Messrs. Chapman & Hall.

Cosmic Rays

A Short Bibliography

(*see page 452*)

No attempt can be made here to give a full account of the large literature on cosmic rays. We give, however, a short selection of papers dealing with the subjects of the present article.

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Some Unusual Applications of the Double Beam Cathode Ray Oscillograph

By G. N. PATCHETT, B.Sc., Grad. I.E.E., Assoc. Brit. I.R.E.*

THE following applications are mainly developments of methods applicable to a single-beam tube but the use of a double-beam tube results in greater accuracy.

The methods all make use of the fact that the Y deflection of the two beams of the normal double-beam oscillograph are 180 degrees out of phase. By connecting the two Y deflecting plates together, two figures are produced, one of which is the "reflexion" of the other.

Measurement of Phase Angle

The usual way of obtaining the phase angle between two voltages (or a voltage and a current) is to apply one voltage to the X plate and the other voltage (in the case of a current the voltage drop across a resistance) to the Y plates. This results in the formation of an ellipse as shown in Figure 1. The phase angle θ is given by the relationship:—

$$\sin \theta = B/A$$

Since the axes are not present on the screen, the measurement of B is not very accurate unless the figure is photographed and the axis drawn on the record.

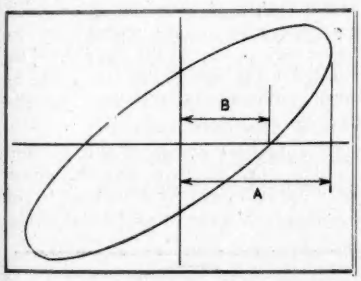

Fig. 1. The ellipse produced by out-of-phase voltages.

By connecting one voltage between earth (anode) and the X plate and the other voltage between earth and the two Y deflecting plates (Y_1 and Y_2), two ellipses are produced, which, by the use of the Y shift controls may be brought level, so as to appear as shown in Figure 2.

The phase angle is now given by $\sin \theta = D/C$.

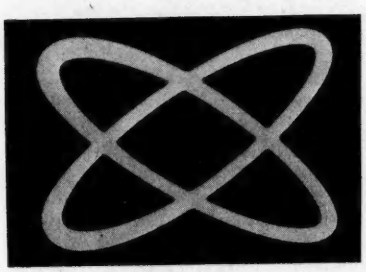

Fig. 3. Photograph of double ellipse on the screen.

(Since $C = 2A$ and $D = 2B$.)

Since in this case measurement of D is made between two points at which the figures intersect and C is made directly across the figure without any reference to the vertical or horizontal axis, the measurements are more accurate and more easily obtained.

A photograph taken from the screen of the cathode ray oscillograph is shown in Figure 3.

Determination of Distortion

Some difficulty is experienced in detecting distortion of a sine wave, particularly when the amount of distortion is only small. Measurement of the distortion produced by an amplifier may be made, in principle, by applying the input to the X plates and the output to the Y plates. In practice, particularly if the amplification is large, the voltage applied to the X plates must be larger than the input to the amplifier. This means either using an attenuator between the X plates and the input to the amplifier, and using large signal or alternatively using a small signal, this being applied direct to the amplifier and through a distortionless amplifier to the X plates. Both methods produce complications.

When the input (X) and output (Y) voltages are in phase, an amplifier with no distortion produces a straight line on the screen of the cathode-ray oscillograph, while distortion is indicated by a curved line. In this case small amounts of distortion are easily detected. When the input and output voltages are not in phase, as is more often the case, a loop is produced on the screen which becomes an ellipse with no distortion present. In this case it is difficult to detect small amounts of distortion, since it is difficult to tell distortion in the shape of the ellipse.

It is sometimes stated that the waveform of the source does not matter when using this method. **This** is only correct if there is no phase shift in the amplifier. **Any distortion in the input will produce distortion of the ellipse (in the case where there** is phase shift in the amplifier) even though the amplifier itself may be distortionless.

The basis of the method to be described is to split up the voltage whose wave-form is to be checked into two voltages, 90 degrees out of phase, by means of the capacity and resistance network shown in Figure 4. The voltage across the condenser is equal to and 90 degrees out of phase with that across the resistance when $R = 1/\omega C$, $\omega = 2\pi f$.

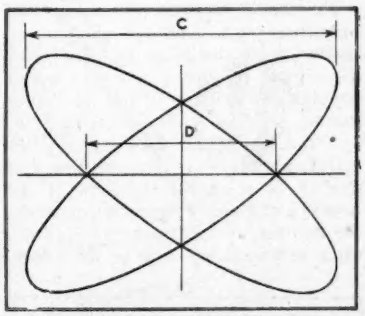

Fig. 2. A double ellipse to give more accurate phase angle measurements.

If the voltage is a pure sine wave a circle is produced. If the wave form is distorted a smaller percentage of the harmonics is produced across the condenser, and a circle is not obtained. Small amounts of distortion are difficult to detect with the single circle, but, by connecting the Y1 and

* Bradford Technical College

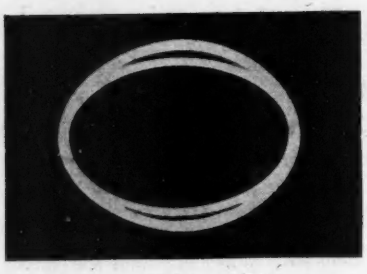

Fig. 5. Superimposed circles to show distortion.

Y2 plates together, another circle is produced which is the " reflexion " of the other (due to the Y deflections being 180 degrees out of phase). By means of the " Y shift " controls the two circles may be superimposed, since they are the same size. Obviously any small departure from the perfect circle can now be seen. A photograph of a trace obtained in this way is shown in the Figure 5. The only distortion which does not show up as the difference between the two circles is that due to odd harmonics whose maximum values are in phase with the maximum value of the fundamental (*i.e.*, distortions which produce similar and symmetrical positive and negative half cycles).

The input waveform when using this method must, of course, be free from distortion when it is used to check distortion produced by an amplifier, etc.

Comparison of Frequencies

The usual way of comparing two frequencies is to modulate the grid or anode of the cathode-ray tube with the higher frequency and produce a circular time base with the other frequency. The former method gives a dotted circle and the latter a gear-wheel pattern. If the higher frequency is an exact multiple of the lower, a stationary figure is produced, the number of dots or teeth being the ratio of one frequency to the other.

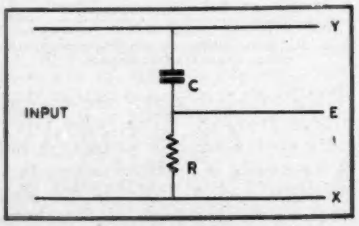

Fig. 4. Simple phase-splitting circuit.

Slight changes of frequency may be detected by the movement of the figure either clockwise or anticlockwise.

By using both beams and connecting the Y plates together two circles are produced, in which the dots or teeth move in opposite directions. Any very slight change in frequency may now be detected by the movement of the dots of one circle relative to the other. A photograph with grid modulation is shown in Figure 6, the circles being slightly displaced for clarity. The frequency ratio is 8/1.

Many interesting figures may be obtained in this way (particularly by the movement of one figure relative to the other by the Y shift controls), *e.g.*, two re-entrant loops[1] may be obtained revolving in opposite directions.

Measurement of Phase Angle (Alternative Method)

The Y plates (Y_1 and Y_2) of the cathode-ray oscillograph are fed through a potentiometer from the

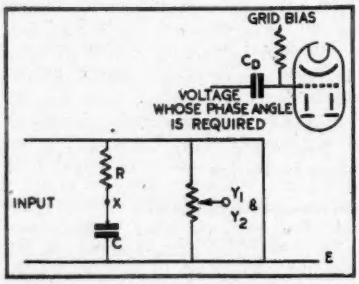

Fig. 7. Alternative circuit for measurement of phase angle.

supply and the X plates from the voltage across a condenser C which is connected in series with a resistance R as shown by Figure 7. By arranging that R is large compared with the reactance of the condenser C, the voltage across C will lag the supply voltage by approximately 90 degrees. Since the voltage across C will normally be small an amplifier will have to be used to feed the X plates. The potentiometer and amplifier gain are now adjusted to give convenient circles on the screen. The voltage whose phase angle relative to the supply, is required is applied between the grid of the cathode-ray tube and earth, through a D.C. blocking condenser C_d.

[1] *Jour I.E.E.* Vol. 89, Pt. 3. p. 191, 1943.

Fig. 6. " Gear-wheel " pattern with grid modulation on the tube.

If the voltage is in phase with the supply two arcs will appear as shown in Figure 8 (assuming that the Y shift controls have been adjusted so that the circles were superimposed), one belonging to each circle. If the voltages are 90 degrees out of phase two arcs are produced as shown in Figure 9, the two arcs actually being superimposed. The actual phase angle may be calculated by measuring θ_1 and θ_2 being obtained from the following relationship :—

Phase angle $\phi = \dfrac{\theta_2 - \theta_1}{4}$, θ_2 being taken as negative when the arcs overlap.

This method gives a direct reading of phase angle not sin ϕ or cos ϕ and is therefore more accurate when the phase angle is only a few degrees or nearly 90°. This method may be used to determine the phase angle of a condenser by placing a resistance whose value is low compared with the reactance of the condenser, in series with it, across the supply. The voltage drop across the resistance is used to modulate the grid of the cathode-ray tube.

One other advantage of this method is that the measurement of phase angle is independent of variations of the supply voltage or variations of the

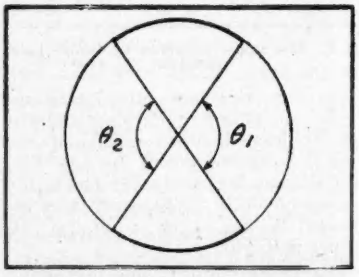

Fig. 8. Diagram of figure on screen with circuit of Fig. 7.

JUST TO BE DIFFERENT

Every so often somebody sits on a pole for a fortnight. Or uses his nose to push a peanut up Pike's Peak. He hopes that novelty will bring him fame and fortune. What he gets is a brief and cheap notoriety : his 'stunt' is without purpose or value. *But, says someone, how about yourselves? Isn't a great part of Simmonds' success due to novelty? Simmonds Stop Nuts, Fram Filters, Simmonds Instruments and Controls—isn't each of them an example of industrial novelty? Don't Simmonds encourage and seek for industrial novelty?* The answer to all these questions is "Yes." If you think you have a novel idea for industrial use you'll find us ready listeners. But we shan't listen long if novelty is *all* you have to offer. To hold our interest, your idea must pass a simple but searching test : "Is a job done better, or more quickly, or more cheaply?" In short, the important thing about any Simmonds product is not that it is novel, but that it is *better*.

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modulating voltage. The effect of increasing the supply voltage is to increase the diameter of the circles, which does not effect the magnitude of θ_1 or θ_2 while variations of the modulating voltage increase or decrease both θ_1 and θ_2 by the same amount therefore not effecting the difference $\theta_2 - \theta_1$. The angles are best measured by a circular protractor placed at the centre of the circles.

Checking the Equality of the Signals in Push-Pull Amplifiers

It is often desirable to check whether the signals in the two halves of a push-pull amplifier are equal and of the same waveform. This can easily be done accurately by connecting the Y_1 plate to one half of the amplifier and the Y_2 plate to the corresponding point on the other half of the amplifier. By adjusting the Y shift controls so that the waves are superimposed it is easy to see whether

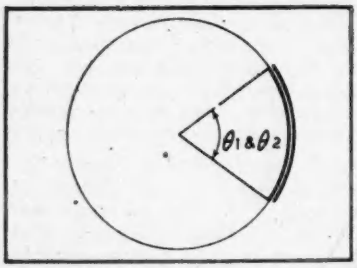

Fig. 9. Figure produced when voltages are 90° out of phase. θ_2 is the obtuse angle.

the two waves have the same amplitude and waveform. This method may be used successfully on normal audio frequency amplifiers and also on push-pull saw tooth amplifiers as used in television and in some cathode-ray oscillographs.

Some intresting and unusual figures may also be obtained by using the fact that the two beams of the oscillograph may also be deflected *in phase* by a magnetic field. The direction of the deflection may, of course, be in the Y direction, the X direction or any intermediate position.

All the above methods have advantages over similar methods using a single-beam tube and require no complications apart from the use of a double-beam tube. Further applications of the above principle may be thought of by readers which would be of assistance to his particular problem.

The Accurate Measurement of Short Time Intervals

THE Microtimer, manufactured by Messrs. R. K. Dundas, Ltd., is, as its name suggests, an instrument intended for the convenient and accurate measurement of short-time intervals ranging from one millisecond to one second. It should find its greatest use in the development and testing of relays, contact breakers, fuses, stroboscopes, camera shutter releases, and all kinds of automatic machinery. Less obvious applications are in measuring viscosity, high accelerations and velocities, speed of chemical (especially explosive) reactions and in the calibration of radiolocation apparatus. The instrument is suitable for operation by unskilled personnel.

The principle is that a large capacitance condenser which has previously been charged by a high voltage D.C. supply, is discharged during the time interval which it is proposed to measure through a constant current circuit into a selected high-stability precision condenser. The voltage developed across this second condenser is a function of the time during which the constant current flowed, and is indicated by a D.C. valve voltmeter of exceptionally high input resistance, stabilised by the introduction of heavy negative feedback. Two diodes are included, one to by-pass the current which charges or leaks through the large condenser which later becomes the source of power for the discharging current, and the second to prevent the charge introduced into the precision timing condenser from leaking out after the interval to be measured has passed.

The standard model is controlled by the making or breaking of two pairs of external electrical contacts; any of the four combinations of makes and breaks can be used. It can also be operated directly without contacts by a photo-cell and valve amplifier. Six ranges with maxima of 10, 20, 100, 200, 500 and 1,000 milliseconds are provided, and in all cases accuracy is within ± 1 per cent. of full scale. Time intervals are read directly on the four-inch long meter scale which is calibrated in milliseconds. Special circuits ensure an almost complete absence of zero drift; the stabilising system renders accuracy totally unaffected by any normal change of valve parameters or in mains supply voltage. The instrument is entirely self contained, normally includes no batteries, and may be connected to any A.C. mains supply; a battery-driven model is available. The meter scale can be supplied with other calibrations (*e.g.*, feet per second, relative viscosity) in cases where the instrument is used under defined conditions for one special purpose.

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High Frequency Therapy

Part VIII.—Therapy Machine Operation—continued

by W. D. OLIPHANT, B.Sc., F.Inst.P.*

IN the previous part we saw that the chief practical advantage of the spark machine over the valve machine lay in its inherent simplicity and robust construction, but from the point of view of output analysis and therapeutic value, the basic differences are much more complex.

While the valve machine generates a sinusoidal oscillation of constant amplitude at a definite frequency defined by the constants of the oscillatory circuit, the spark machine generates an oscillation of varying amplitude and at a number of possible frequencies related to some fundamental frequency. In the former case we have what are known as undamped oscillations, while in the latter we have damped oscillations.

In any undamped oscillation generator the instantaneous value of the output current i is given by the expression:—

$$i = I.\sin\omega t \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where I is the current amplitude and ω is the angular frequency. The quantity ωt is the phase angle, which in terms of the period of oscillation τ, is equal to $2\pi t/\tau$.

The ratio t/τ is known as the *phase* of the oscillation.

This simple oscillation may be represented graphically by considering the projection of a rotating radius vector of constant magnitude I on an arbitrary time axis which is normal to the axis of reference (zero time); the constant angular velocity of rotation is ω radians per sec.

A damped oscillation, on the other hand, may be represented graphically by considering the projection of a rotating radius vector whose magnitude varies in such a manner that the vector extremity traces out a logarithmic spiral.

The instantaneous current output is now expressed in the form:—

$$i = I.e^{-at}\sin\omega t \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where a is known as the *damping exponent* and e is the base of Napierian logarithms.

The quantity $a\tau$ is known as the *logarithmic decrement* of the oscillations, and is usually denoted by the symbol δ or d.

It can be shown that for a simple circuit comprising inductance L, capacitance C, and effective resistance R, that

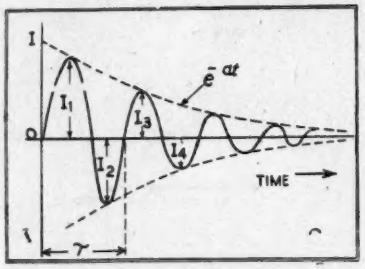

Fig. 1. Train of damped waves produced by spark generator.

$$a = R/2L$$

Hence,

$$d = a\tau = (R/2L)(2\pi\sqrt{LC}) = \pi R\sqrt{C/L}$$

where $\sqrt{LC}$ is the oscillation constant of the circuit. We see from Eqn. (2) that the successive current maxima decrease in accordance with an exponential law and that the actual logarithmic decrement can be calculated at once from a knowledge of the circuit parameters.

The effective resistance, which takes into account radiation loss as well as circuit loss, is here assumed to be constant, but as soon as a spark gap is introduced into the circuit this is no longer the case. A typical damped train of oscillations is shown in Fig. 1.

In terms of the successive current amplitudes shown, the logarithmic decrement per half-period is given by:—

$$d = \log_e\frac{I_1}{I_2} = \log_e\frac{I_2}{I_3} \text{ etc.}$$

or $e^d = I_1/I_2 = I_2/I_3$, etc.

Hence e^d is the factor by which we have to multiply any amplitude to obtain the preceding one. Thus in terms of the first current amplitude I_1, we obtain an alternative expression to that given in Eqn. (2):—

$$i = I_1.e^{d/\tau}e^{-at}\sin\omega t \quad \ldots\ldots\ldots \quad (3)$$

This is the expression for the value of current at any time t reckoned from the instant of starting the oscillations.

In dealing with the spark machine we have a series of wave trains which are generated at a rate of N trains per second, N being the recurrence or spark frequency. The problem is now to determine the integral value of such a series of oscillations, that is to say, the value of which, when multiplied by the effective resistance of the circuit will give the average rate of heat production.

It can be shown that

$$\overline{I^2} = N.I_1^2.e^d.\frac{\omega^2}{4a(a^2+\omega^2)}$$

where $\overline{I^2}$ is the mean square value of the current and I_1 is the first current maximum in the wave train occurring at a time $\tau/4$ reckoned from zero time.

Now $\omega = 2\pi n$ and $a = 2nd$.

Hence $$\overline{I^2} = \frac{N.I_1^2.e^d}{8nd}\left\{1 + \left(\frac{d}{\pi}\right)^2\right\}^{-1}$$

In practice, when $d/\pi \ll 1$, the term within the brackets may be taken as unity, in which case

$$\overline{I^2} = \frac{N.I_1^2.e^d}{8nd} = \frac{N.I_1^2.e^d}{4a} \quad \ldots\ldots\ldots \quad (4)$$

Thus the rate of heat production is proportional to the square of the first current amplitude in the train, to the spark or recurrence frequency, but is inversely proportional to the frequency of oscillations in the train and to the logarithmic decrement.

In operating any spark machine, therefore, it is advisable to have as high a spark recurrence frequency as possible and to keep the output circuit damping as low as possible.

In the primary or tank circuit, the resistance of the spark must be included in the damping calculation. The spark resistance is dependent on a number of factors such as length of gap; the initial quantity of electricity flowing at the instant of initial breakdown; the operational circuit frequency and the recurrence frequency as well as the material and nature of the gap electrodes and intervening gas. In practice, the gap resistance for a given set of conditions, is not constant and so the characteristic of the output is continually changing due to gap resistance instability. The output is further complicated by a large number of harmonic components due to shock excitation effects.

Since the patient circuit is coupled to the tank circuit and is shock excited, it follows that the induced wave trains are of longer duration due to the lower damping. Thus the gap interval between trains is shorter, and the integral value of the current is higher.

* University of St. Andrews.

As soon as damping increases due to loading, the gap intervals become longer and so the output is reduced considerably. These points are demonstrated in Fig. 2

The effect of harmonics in the tank circuit on the output will depend on the selectivity (or damping) of the patient circuit. Thus the harmonic content in the output of a lightly loaded machine will be less than that in a heavily loaded machine, and in this connexion the insertion of a tertiary circuit, to act as a filter, might in certain circumstances prove beneficial.

Operational Protection

Machine Screening

It is a matter of experience that development engineers working in close proximity to ultra-high frequency drive oscillators experience certain nervous disorders, rises in body temperature, and suffer fits of depression. These are due to physiological effects brought about by the incidence of electric waves radiated from the oscillator on the human body; or, by exposure to the intense electric or magnetic fields associated with circuit components. In the case of a pair of spaced patient electrodes, the power lost by radiation, while being proportional to the square of the output current, is directly proportional to the square of the electrode separation and is inversely proportional to the operating wavelength squared. Thus the output connexions provide some kind of aerial system which brings about a reduction in overall efficiency. As far as the operator is concerned, his body may be regarded as a dipole and at wavelengths of the order of 3 metres, he is just about tuned to pick up the maximum amount of radiated energy; he, too, will experience a heat sensation along with his patient. The erection of some light metallic screen will provide sufficient protection for the operator under these conditions. As the machine itself is invariably assembled in a metal cabinet (which must normally be earthed) stray fields due to circuit components are confined to the interior of the cabinet provided due attention is paid to the efficient bonding of the metal panels and constructional members.

Interference with Telecommunication Channels

The development of the application of radio to medicine has been aided largely by the advances made in other spheres of radio engineering and many of the basic physiological effects (already cited in the previous section) were noted for the first time by broadcast engineers. To these engineers any form of interference is a thorn in the flesh and the high frequency therapy machine is no mean offender unless suitable steps towards suppression are taken. The therapy machine is a potential low-powered transmitter and the patient electrodes and leads, to say nothing of the patient himself, form a crude aerial system, so that a strong radiation field is set up. This field causes very serious interference with communication channels such as the broadcast and television services, and, as the majority of therapy machines are located in hospitals and in practitioners' residences, all within densely populated areas, steps must be taken to suppress at the source. In addition to the radiated interference, there is also the possibility of energy being transmitted back along the supply mains to which the machine is connected.

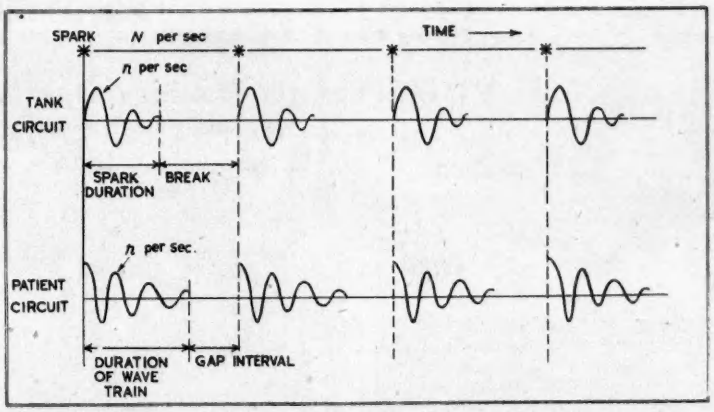

Fig. 2. Showing relation between wave trains in patient and tank circuits in spark generator.

We have already seen that the power radiated from a pair of spaced patient electrodes is inversely proportional to the square of the operating wavelength, and so with the downward trend in wavelength both in therapy and in telecommunications, the interference effects are going to increase. This effect is further augmented by the fact that the length of the electrode leads themselves become of the same order of magnitude as the wavelength, thus increasing the overall radiation efficiency.

In the case of valve machines the interference will take place at the fundamental frequency but there will also be interference due to the presence of harmonics; these will, however, all be tunable. In the spark machine, on the other hand, interference will appear as a continuous spectrum over a very wide range of frequencies.

Some idea of the order of magnitude of the radiation field set up can be obtained by the following figures which are quoted from a paper by A. J. Gill and S. Whitehead ("Electrical Interference with Broadcast Reception," *J.I.E.E.*, *83*, 345, Sept. 1938).

In the case of a 0.3 kw. valve machine operating on a fundamental frequency of 42.5 Mc/s. and fed on the anode with raw A.C., the peak radiated field strength in db. above 1μV/metre was found to vary from 90 db. in close proximity to the machine, through 60 db. at 300 yards, 50 db. at 1,000 yards, to just over 45 db. at 1,400 yards distance. Removal of the patient leads in this particular experiment resulted in an overall reduction in field strength of about 10 db. The effective band width, referred to a level on either side of the fundamental frequency of 40 db. below peak, was of the order of from 500 kc/s. for the fundamental to 150 kc/s. for the 5th. harmonic. Harmonics, which fell off much more rapidly with distance, nevertheless gave for a fundamental frequency of 7.6 Mc/s., field strengths of the order of 45 db. and 30 db. for the 3rd and 5th harmonics respectively at 100 yards distance.

In the case of a spark machine delivering 2 amperes at a nominal fundamental frequency of 37.4 Mc/s., the peak field strength (again in db. above 1 μV/metre) at the fundamental frequency fell off from 65 db. at 25 yards, through 45 db. at 100 yards to just over 27 db. at 350 yards distance from the source. The variation of intensity with frequency can be judged from the following set of results taken at a fundamental frequency of 37 Mc/s. The peak field strength at a fixed distance from the source for the fundamental frequency

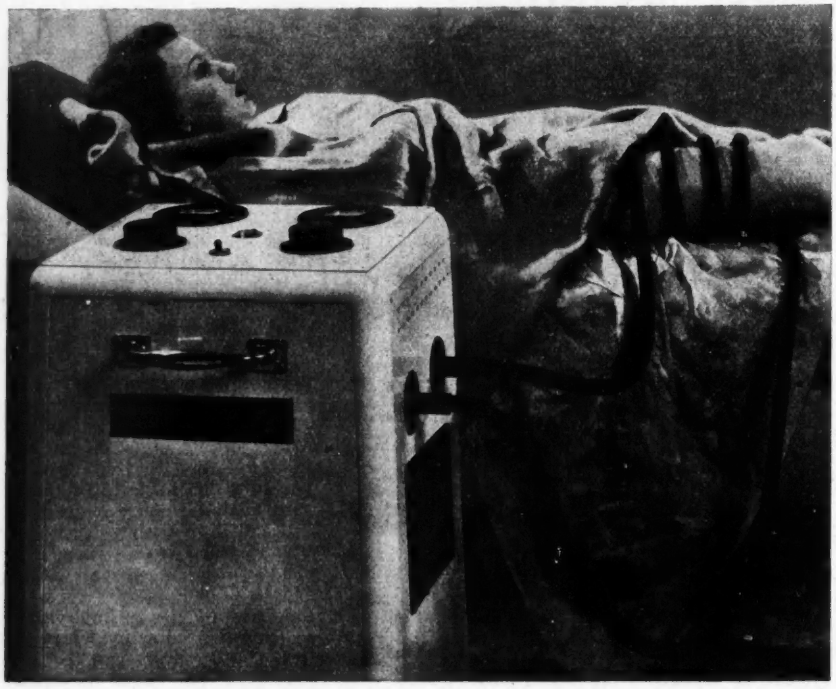

Fig. 4. Machine for Inductothermic treatment.
(*By courtesy of Messrs. Stanley Cox*)

was 100 db. above 1 μV/metre, and the mean level of interference peak field is of the order of 90 db. above 1μV/metre over a frequency range of from 20 to 48 Mc/s.

In the case of a 300 metre spark machine, the mean level of interfering intensity over the same frequency band was of the order of 50 db. above 1 μV/metre.

For the television service, Gill and Whitehead estimate that the tolerable signal to noise ratio for sound is 40 db., while for vision is of the order of 16 db. These figures are based on a receiver h.f. band width of 60 kc/s. for sound and 4 Mc/s. for vision. It is thus necessary to suppress the therapy machines to comply with this criterion at least.

In order to suppress the interference, which is essentially a direct radiation, there are two possible methods. Firstly, the dimensions of the output circuit could be so chosen as to be small compared with the operational wavelength and so bring about a lowering of the equivalent aerial efficiency. To the research worker, this method would appeal, but as far as the general practitioner is concerned it would provide an added complication. The second method which, though technically the simplest, is, nevertheless, the more costly, is to enclose the entire machine, together with the patient, in a screened cubicle or room, and to provide a suitable filter circuit in the mains supply connexion to the machine and cubicle lighting circuits. For this room to act as an efficient screen, great care must be taken to ensure that the metal sheets employed are efficiently bonded together. This bonding is particularly important at the door so that no discontinuity in the metallic sheath may occur when the door is closed. Ventilation apertures must be provided with a metal gauze shutter and so on. Metallised wall paper has been produced in an attempt to convert the average room into a screened one but, unfortunately, the efficiency of such a screen decreases with age due to the increase in the electrical resistance between seams. A room so papered would require special fittings to be attached to doors and windows to provide the screen continuity. A direct metallic spray on the walls of a room would seem to be a much more promising method and doubtless such methods will some day mature. At the higher frequencies the screened cubicle can take the form of a wire gauze cage, in which case a more portable erection can be assembled round the machine and patient, but again a high screening efficiency is dependent on good bonding.

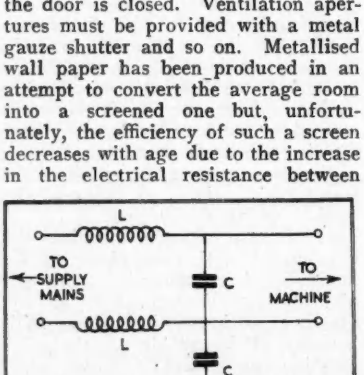

Fig. 3. Filter circuit for suppression of mains-borne interference.

In order to suppress mains-borne interference a filter such as is shown in Fig. 3 should be inserted, the values for L and C being chosen to meet the particular requirements of a given installation.

Inductothermic Therapy

Our analysis up to the present has dealt exclusively with the use of condenser electrodes and with the properties of the condenser field, the body being regarded as part of the dielectric medium. Heat effects could equally well have been produced by placing the body within the magnetic field due to the passage of a high frequency current through a suitable inductor. In the inductothermic method a few turns of insulated flexible cable are wound round or about the part to be treated, and this coil is connected across the output terminals of the machine. The method is particularly suited to the treatment of the body extremities and Fig. 4 illustrates the use of such a cable in a treatment of the upper leg.

The principle of the method is based on the well-known engineering process of eddy-current heating. The maximum heat will be generated more readily in the conductive or vascular tissue than in the less conductive or adipose tissue. Many users of this method indicate its special advantage over the condenser field method in the production of hyperpyrexia.

The operating adjustments are similar to those already outlined except that it is now the effective inductance of the coiled cable which must be used in conjunction with the other output circuit constants to establish resonance. Many machines are equipped for both capacitor and inductor methods of treatment.

APRIL MEETINGS

Institution of Electrical Engineers

London Section

Ordinary Meeting

On April 27, at 5.30 p.m., the Thirty-Fifth Kelvin Lecture will be held. Professor E. C. Stoner, Sc.D., F.R.S., will lecture on "Magnetism in Theory and Practice."

Measurement Section

The next meeting will be held on April 21, at 5.30 p.m., and a paper will be given by L. Jacob, M.Sc., Ph.D., on "A New Type of Electron-Optical Voltmeter."

Wireless Section

At the meeting to be held on April 5, at 5.30 p.m., a lecture will be given by D. Gabor, Dr. Ing, on "Energy Conversion in Electron Valves."

Students' Section

Two visits have been arranged for this month, the first being on April 15, at 2.30 p.m., to Battersea Power Station. The second will be on April 26, to Messrs. Siemens Bros. and Co., Ltd., Woolwich, at 2.30 p.m. Applications for tickets should be made to the Secretary of the I.E.E., giving name, address, nationality, and National Registration number.

The next meeting will be held on April 3, at 7 p.m., and a paper will be given by B. J. Prigmore, B.A., on "Motor Coach Trains and Their Operation on British Suburban Railways."

On April 26 another paper will be read by Mr. J. W. Bayliss on "Industrial Heating at Radio Frequencies."

Cambridge and District Wireless Group

At the meeting to be held on April 17, at 5.30 p.m., at the Cambridgeshire Technical School, the address will be given by Mr. B. J. Edwards, on "A Survey of the Problems of Post-War Television."

Brit. I.R.E.

At the next meeting to be held on April 27, at 6.30 p.m., at the Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1, a paper will be read by P. Adorjan (Member) on "Development of Wired Broadcasting."

The Association for Scientific Photography

The next meeting of the above will be held on April 29, at 2.30 p.m., at Caxton Hall, Westminster, S.W.1. A paper will be read by J. Yule Bogue, Ph.D., M.R.C.V.S., entitled "The Rôle of Photography in Agricultural Investigation."

Institute of Physics

On April 21, at 6 p.m., in the Rooms of the Royal Society, Burlington House, Piccadilly, London, W.1, the lecture will be given by Professor E. J. Williams, F.R.S., on "Cosmic Rays."

Industrial Radiology Group

The meeting of the above to be held on Saturday, April 22, at 2.30 p.m., at the Royal Institution, Albemarle Street, Piccadilly, London, W.1, will take the form of a discussion on the paper by W. H. Glaisher, B.Sc., W. Betteridge, Ph.D., F.Inst.P., and R. Eborall, B.A., entitled "The Mottling of Aluminium Alloy Radiographs."

Institution of Electronics

A joint meeting of the North-Western Branch of the above Institution and the Manchester and District Branch of the Institute of Physics, will be held at the Reynolds Hall, College of Technology, Manchester, at 7 p.m., on Friday, April 14.

The lecture will be given by D. Gabor, Dr. Ing, F.Inst.P. (B.T.H. Co., Ltd.), on "Electron Beams."

Application for tickets of admission should be made to the Honorary Secretary, 14 Heywood Avenue, Austerlands, Oldham.

British Kinematograph Society

The next meeting will be held on April 12, at 6 p.m., at the Gaumont-British Theatre, Film House, Wardour Street, W.1. The address will be given by Oliver Bell, on "Recent Advances in Educational Film Presentation."

Electronic Music Group

The next meeting of the above will be held on April 1, at 2.30 p.m., at the Northern Polytechnic, Holloway Road, London, N.7. A paper will be read by Mr. S. K. Lewer (G.E.C.) entitled "Problems in Electronic Organ Design."

The Television Society

The next meeting of the Society will be held at the Institution of Electrical Engineers, Savoy Place, W.C.2, on Saturday, April 22, when a paper on "The Manufacture of Cathode Ray Tubes" will be read by Mr. T. D. Humphreys.

Tickets of admission for non-members can be obtained from the Editorial office of this journal.

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An Electronic Baby Alarm

By J. S. WORTHINGTON

THE apparatus described was designed and constructed to meet the need of a warning that a baby was awake and crying, the bedroom being some distance from the sitting room and cries very difficult to hear (especially if the radio were on!). It could also be arranged to give a warning in the garden or anywhere else required. The sensitivity is such that a low moan or whimper two feet from the microphone will cause a relay to close, so operating a buzzer at the remote point.

The heart of the unit is the rectified reaction stage shown in Fig. 1. The valve is biased so that the relay will just release after being operated. When a signal is impressed on the grid it is amplified and fed back via C_3 and the rectifier-R_3 network. Due to the rectifier a D.C. voltage is built up across R_3 in opposition to the fixed negative bias. This is applied to the grid through the de-coupling resistor R_1 and this results in increased anode current being passed and the relay operates.

Using a carbon microphone of the usual P.O. type with 20 mA current through it, good results were obtained with this circuit, but sensitivity was hardly adequate for the purpose, though normal speech one foot from the microphone gave reliable operation. The relay used was a 3,000 type (P.O.) of 1,000 ohms resistance, operate current 2.1 mA, release current 0.5 mA. No doubt a more suitable relay would improve the sensitivity, but such things are not easy to obtain in war-time.

To obtain adequate sensitivity an amplifying stage was added, resistance-capacity coupling being used with a high-mu triode (H63). This resulted in the circuit arrangement shown in Fig. 2. The amplifying stage is normal in every way; neon bulb stabilisation of H.T. voltage was incorporated, and the adjustable bias necessary for the relay valve was obtained from a potentiometer across the supply. The neon lamp was of the pilot lamp type and was actually mounted behind an aperture in the panel to serve as an indication that the power was on.

The apparatus at this stage performed its duties very satisfactorily, but it was realised that it also contained the essentials of an efficient pre-amplifier and in these days of shortages the prospect of combining several functions in one piece of apparatus had great attractions. By providing an input volume control and arranging to use the feed-back

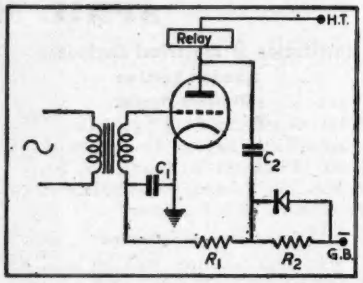


Fig. 1. Basic circuit of 'rectified reaction' relay amplifier.

condenser C_3 and the impedance of the relay winding as output coupling components and disabling the rectifier network, a high gain, high quality amplifier was available. These changes were made quite simply by incorporating an output jack which was made to perform the necessary switching as shown in Fig. 3. The cathode by-pass capacity was also increased and a dual purpose input transformer installed. An additional refinement incorporated at this stage was the inclusion of a resistor in the negative return lead to provide microphone energising current and so eliminate the microphone battery. The heater supply was used to operate the remote buzzer to make the unit completely self-contained. When used as a straight amplifier the bias control for V_2 should be set so that the valve draws its normal anode current for class A operation. An attempt was made to improve the operation by including a proper coupling choke in series with the relay winding, but the improvement when used as a straight amplifier was negligible and operation as a relay was impaired owing to the consequent slowing of the D.C. current rise and fall due to the inductance, so it was omitted in the final version. Adjustment is very simple, all that is necessary being to reduce the bias on V_2 by the variable resistor until the relay operates, then, making sure the microphone is plugged in and

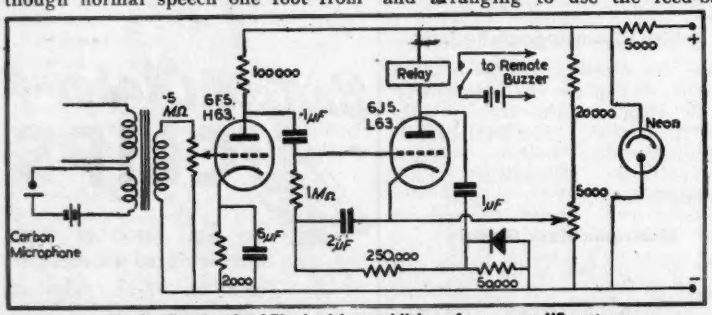


Fig. 2. The circuit of Fig. 1 with an addition of a pre-amplifier stage.

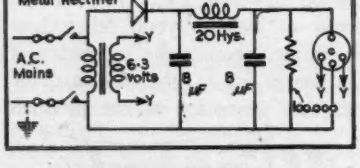
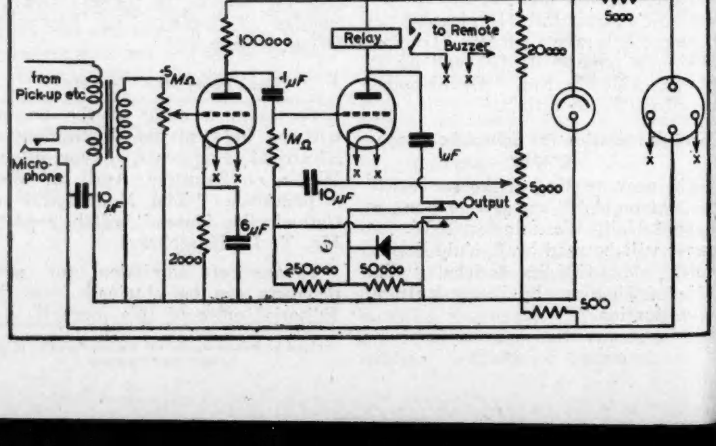


Fig. 3. (right) The circuit adapted for use as a high-quality amplifier.

Fig. 4. (above) The power pack.



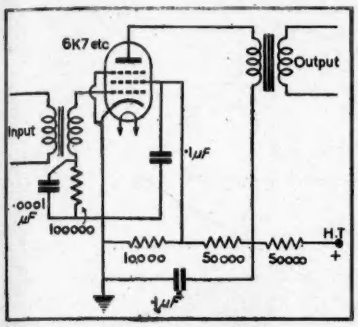


Fig. 5. Limiter stage for controlling output.

the input volume control at maximum, increase the bias slowly until the relay just releases. After this the input volume control can be set to operate at any desired level.

The power supply used for this apparatus is fed directly from the A.C. mains. This circuit is only suitable where one side of the supply mains is earthed and care must be taken to see that the earthed side is so connected that it becomes the negative side of the H.T. output as one side of the microphone circuit is directly connected to negative H.T. The filter shown proved adequate to reduce the hum sufficiently for relay working though an additional filter section is desirable for use as an amplifier. For this reason the power supply was built as a separate unit, both units being provided with valve sockets for termination of supplies and connected together by a multi-core flexible cable fitted with a valve base "plug" at each end. When operation as an amplifier is desired a high quality power supply, normally used for other purposes, is plugged in in place of the simple unit described above. This system of inter-connexion has long been adopted as standard on all the writer's apparatus and has proved very flexible and convenient.

The uses to which the Rectified-Reaction Relay Amplifier can be put are many. For instance, it is very suitable for controlling a tape recorder from the output of a receiver. High level input is not essential, reliable operation being obtained with a peak A.C. input to the stage of 1 volt. In such an application it is advantageous to use a limiter stage between the receiver output and the relay stage to smooth out any variations in signal strength. Such a limiter stage is usually of the anode saturation type where low anode and screen voltages are used to limit the anode current at high signal amplifiers. A suitable circuit is shown in Fig. 5.

NOTES FROM THE INDUSTRY

Are Gauges Really Necessary?

The *Production and Engineering Bulletin*, in its March issue, tells of a blind woman who was being interviewed for employment as an inspector. She was given three ring nuts as a specimen of the work she would have to handle, and on feeling them put one aside as the smallest of the three. The micrometer test showed that it was 0.017 in. under size! A second blind applicant was then given the two remaining ring nuts and calmly said that one was smaller than the other. So it was, to the amount of 0.004 in.!

It has been stated that blind inspectors can attain a 50 per cent. greater output of inspection than sighted ones.

"Ardux" Plastic Cement in Powder Form

Messrs. Aero Research, Ltd., announce that they have now succeeded in producing their "Ardux" plastic cement in the form of a powder, which overcomes the drawback of the limited keeping time of the liquid.

The powder is readily miscible with a mixture of water and methylated spirit to form a liquid adhesive of any desired consistency. The setting time is faster than that of Ardux I and Ardux II, which should effect economies in the production time of transformer bobbins and inserts, etc.

At a temperature of 150° C. in the glue line, the cement sets in three minutes. The dry powder will keep for six months, and the mixed cement liquid for some days in closed containers.

Copper Alloy Resistance Materials

A booklet recently issued by the Copper Development Association describes the characteristics and use of copper-nickel, copper-manganese and similar resistance alloys, together with notes on the construction of resistances and rheostats. A very useful booklet, obtainable from the Copper Development Association, 9 Bilton Road, Rugby. Ref. C.D.A. No. 38.

Taylor Instruments New Catalogue

Messrs. Taylor Instruments have recently issued a new catalogue covering their range of meters and test instruments in a summarised form. Copies will be sent to all engineers and firms who are interested.

Trix Electrical Co., Ltd.

This company was wrongly referred to as Messrs. Trix, Ltd., in the Notes in last issue. They are, of course, well known as manufacturers of P.A. and radio equipment.

A British Radio Research Institute?

The British Institution of Radio Engineers have submitted proposals for the formation of a British Radio Research Institute for "the pursuit of basic research of the type that has hitherto suffered restriction owing to its high cost, absence of obvious or immediate practical applications, or the poor prospect of early financial return."

The Institute would be financed by Government grants and industrial subscriptions, and directed by an impartial body comprising representatives of the Government authorities and the Services, the Industry, Universities and the Brit. I.R.E.

It is pointed out that the work of the Institute would not encroach on that of Government Research Establishments and it is not proposed to restrict the application of private research by independent firms. Full co-operation with the Commonwealth is recommended. Copies of the proposal can be obtained from the Secretary, the British Institution of Radio Engineers, 9 Bedford Square, W.C.1.

The Muirhead-Wigan Oscillator

In the letter from Mr. W. C. Lister (Messrs. Muirhead & Co.), published in last month's issue, the omission of a date made the statement lose some of its point.

This was that the Muirhead-Wigan oscillator circuit was developed independently by the late Mr. P. W. Willans as early as 1937, and the patent application was filed in April of that year.

The letter should have appeared some time ago but was unfortunately overlooked and we hope that this explanation will clear the matter up to Messrs. Muirhead's satisfaction.

Obituary

The death has occurred, at the age of 69, of Mr. W. C. Lusk, deputy chairman and managing director of Associated Electrical Industries, and chairman of the B.T.-H. Co. and other companies. He was trained at Yale, and before joining the B.T.-H. Co. was with the G.E. of America. He took a leading part in the formation of the A.E.I. in 1928.

The death is also reported of Dr. L. H. Baekeland, the well-known plastic pioneer and the father of Bakelite. It is not generally known that he was also the inventor of "Velox" photographic paper, which is marketed by the Kodak Co. He was born in Ghent in 1863, and died last February.

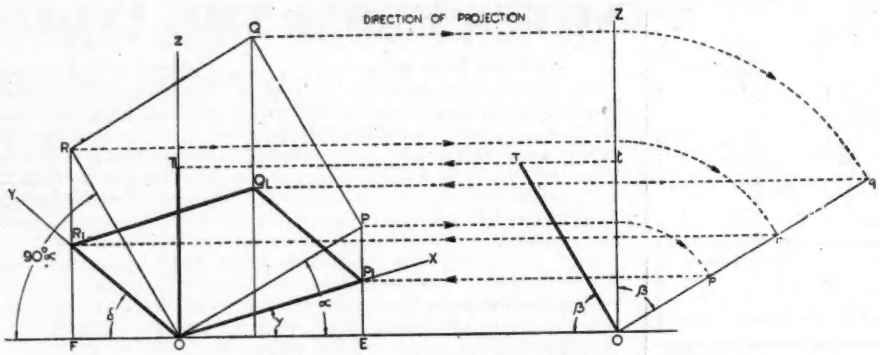


Fig. 1. The development of trimetric projection.

Trimetric Projection

MOST readers will have experienced, at least occasionally, some difficulty in visualising an object in the solid from its projected appearance in an ordinary engineering drawing. Perspective and isometric drawings are a great improvement in this respect, but in one case they require the service of a professional artist or highly skilled draughtsman and in the other provide a single, rather unreal view. What is wanted is a drawing giving the appearance of the subject in perspective, but correctly to scale in all three dimensions, and at the same time easy to construct. The draughtsmen of the Metropolitan-Vickers Co. have found the ideal solution for this problem. What is more, there is a choice of viewpoint available to suit the character of the subject in depth.

This important new development is a special scale based on the system known as "Trimetric Projection." The construction for this projection will be obvious from examination of the drawing in Fig. 1. The square assumes the appearance $OP_1Q_1R_1$ in trimetric projection, the side elevation making clear the manner in which this has been arrived at. The line OT represents one of the perpendicular edges of the third dimension. An elementary knowledge of trigonometry will demonstrate that the lengths OP_1, OR_1 and OT_1 can each be calculated in terms of the two angles γ and δ which decide the degree of bird's-eye viewing obtained. Thus the desired choice in view is provided and all three dimensions are strictly to scale.

The trimetric scale embodies these scales, which can be determined graphically or by calculation.

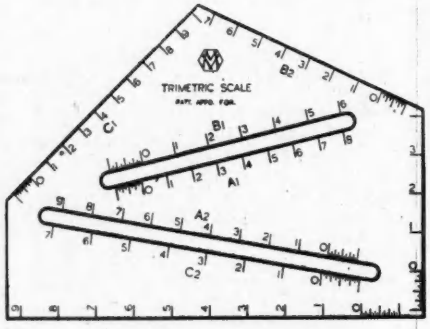


Fig. 2. The trimetric scale.

A patent application has been filed for this device, which has been designed by Messrs. J. P. Simpson and J. Stewart in the drawing offices in Trafford Park. The trimetric scale, shown in Fig. 2, has three sets of scales: A_1A_2, B_1B_2 and C_1C_2, each based on a different combination of angles γ and δ, thus giving three "lines of sight" and, if turned over, these three views reversed. The scales have been calculated in the above manner, but, for convenience, the vertical scale (OT_1) has been modified to unity and the other two OP_1 and OR_1 (*i.e.*, A and B) corrected accordingly.

A small amount of reflexion will enable the reader to gather some idea of the possibilities of this system of drawing. The item in Fig. 4, for instance, is an everyday type with which many departments are concerned. The designer, the production engineer, estimator, foreman, inspector, supervisor, salesman, shipper, storeman and others in succession require to gain a quick and clear impression of scores of such commodities during the course of a day. For this purpose trimetric drawings are invaluable and provide an appreciable and cumulative saving in man-hours throughout the whole length of the chain of production.

Still more advantage is gained by the operative on the work itself. A trimetric sketch makes the job almost self-explanatory, so that little time is wasted in imparting instructions. Those familiar with works conditions brought about by the influx of unskilled labour will at once recognise the immense saving possible. A junior worker with a minimum of training can be given a task or transferred from one duty to another with virtually no interrruption in production when guided by trimetric drawings. Moreover, skilled labour relieved of much instructional work is released for more appropriate activities. Supplies of the special scale are expected to be available shortly, and trimetric projection will doubtless be widely known and practised in the near future.

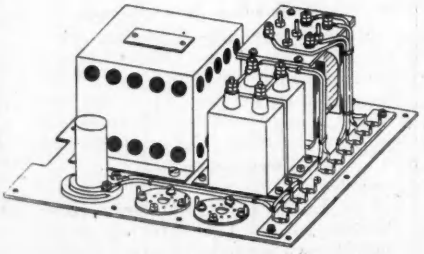
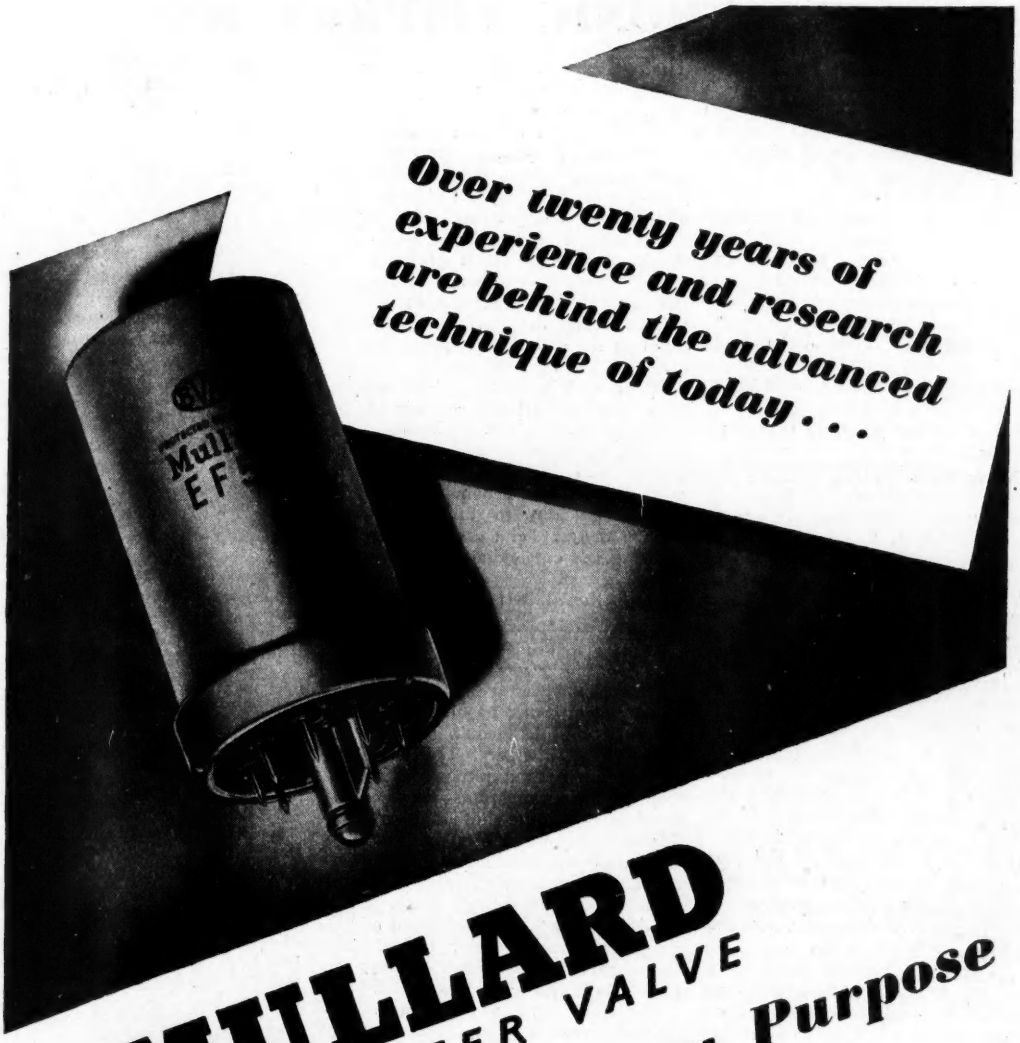


Fig. 4. A typical wiring-up assembly (Scale A_1 A_2).

—*Metropolitan-Vickers Gazette*



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ABSTRACTS OF ELECTRONIC LITERATURE

High Speed Automatic Infra-Red Spectrometer
(E. B. Baker and C. D. Robb)

A rocksalt, vacuum, double monochromator is described that displays the entire spectrum out of 15μ (or selected portions thereof at higher resolution) in one minute on a long-persistence oscilloscope screen. It measures per cent. transmission directly, automatically correcting for source-intensity distribution and spectrometer losses. Special arrangements permit rapid preparation of samples for analysis. Reflexion measurements and direct comparison of two emission sources can also be made.

—*Rev. Sci. Inst.* Vol. 14 (1943), p. 362.

Valve Amplification Factor
(H. Herne)

A new treatment of the electrostatic field of a triode is outlined, and it is shown to be valid for values of the grid wire diameter from zero to two-thirds of the grid pitch. A formula for the amplification factor of a planar triode is deduced, and it is shown to be the product of two factors, the first dependent on the grid geometry alone and the second on the anode to grid plane spacing; a graph is given for the rapid evaluation of the amplification factor of specific geometries. The extension of the method to other geometries and to multi-grid valves is indicated.

—*Wireless Engineer.* Vol. 21 (1944), p. 59.

Heat Capacity of Fine Wires
(B. Kurrelmeyer, W. H. Mais and E. H. Green)

A wire enclosed in an evacuated tube is placed in one arm of a Wheatstone bridge and brought to the temperature at which its heat capacity is to be determined. With the bridge balanced, galvanometer key closed, and battery key opened, a charged condenser is connected across the battery terminals of the bridge. The heat capacity is evaluated from the resulting ballistic deflection. In an alternative procedure, the bridge is initially unbalanced so that discharge of the condenser gives zero deflection. The method has been tested on pure platinum in the neighbourhood of room temperature. The overall accuracy is estimated at $\frac{1}{2}$ per cent. The internal consistency is much better. A table is given of the authors' results together with the best previous measurements.

—*Rev. Sci. Inst.* Vol. 14 (1943), p. 349.

Tuning Fork Standards for Meter Calibration
(D. E. Anderson)

A brief review is given of a method of checking frequency meter calibrations against some reliable standard giving average frequency deviations of less than 0.04 per cent. An installation comprising 15 tuning fork electronic oscillators which provides accurate standard frequencies is briefly described. Stroboscopic light is used to standardise the oscillators at every point in the common frequency range and the standard frequency is available to each operator. The output from each oscillator is carried by ordinary battery cable circuits to a number of points at which small amplifiers convert the voltage from a relatively high impedance circuit into power sufficient to operate a frequency meter. The oscillator circuit showing the connexions to fork coils, etc. is given.

—*El World.* 8/1/44, p. 92.*

Recent Developments in the Electron Microscope
(V. K. Zworykin and J. Hillier)

During the past year, considerable development work has been done on the various optical components of the electron microscope. The effect on the specimen illumination of the electron gun focusing has been calculated. The results show that for some adjustments of the electron gun, the condenser of a conventional microscope exerts practically no control over the illuminating beam. The resolving power of an electron microscope objective has been investigated thoroughly with and without a physical limiting aperture. It was found that for heavy specimen particles the resolving power was roughly twice as good with a limiting aperture as it was without. The best resolving power obtained was 24A. The distortion of the final image caused by the projection lens errors has been investigated, and methods for greatly reducing this distortion have been found. A small magnetic electron microscope has been developed. The resolving power obtained at present exceeds 50A. This instrument uses no condenser lens, while the objective and projection lenses are incorporated in a single magnetic circuit excited by a single regulated current supply. Internal photography is used although, because of the small volume, no air locks are necessary.

—*Phys. Rev.* November 1-15, 1943.

Magnification Calibration of the Electron Microscope
(E. F. Fullam)

A method is proposed for the magnification calibration of the electron microscope to compensate for the calibration errors caused by mechanical and electrical variations of the instrument. The method uses microscopic glass spheres of predetermined size mounted directly on the specimen supporting film, one of which is exposed on the same photographic plate as the specimen. Errors due to instrument variations are eliminated as any change in the magnification of the specimen also causes a corresponding change in the magnification of the sphere. It is claimed that an accuracy of about ± 3 per cent. is attained.

—*J.App.Phy.* Dec., 1943, pp. 677-683.*

A Compact High Resolving Power Electron Microscope
(V. K. Zworykin and J. Hillier)

The early development of the electron microscope is traced. When it was realised after the initial stages that the instrument promised to be a useful laboratory tool, greater stress was placed upon reliability of performance, ease of operation and simplicity of construction. The author makes an extensive survey of the desired instrument qualities and describes an experimental design of a small electron microscope made by the R.C.A. laboratories. This instrument is mounted on a desk at an angle of 20 degrees, the effective viewing screen being 9 in. in diameter at a total magnification of 15,000. The remainder of the microscope equipment is mounted within the confines of the desk. A detailed description of the instrument is given.

—*J.App.Phy.* Dec., 1943, pp. 658-677.*

Temperature Coefficient of Capacitance
(W. Schick)

The paper discusses the requirements for the measurement of temperature coefficient of capacitance of small radio condensers, and analyses possible errors with a view to defining conditions for the achievement of a certain accuracy. Various electrical and thermal methods are then reviewed as a preliminary to the description of an apparatus which was specially designed for the purpose.

—*Wireless Engineer.* Vol. 21 (1944), p. 65.

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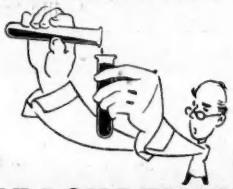

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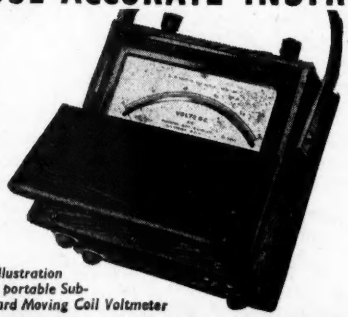

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Modern Radio Servicing

A. A. Ghirardi, B.S. 1276 pp. 706 figs. (Radio & Technical Publishing Co., 31s. 6d. British price).

This book was originally published under the title "Radio Servicing Course" but the present edition is so completely revised and expanded as to constitute a new volume. It might well be called the "Service Engineer's *Vade Mecum*" as nothing of importance in radio work has been omitted.

The whole book is divided into three parts: the first dealing with apparatus and methods, the second covering the various tests themselves, and the third, installation of special types of receivers.

In the first part there are detailed instructions for making up all types of test gear, with examples of commercial instruments. The practical servicing section devotes a considerable space to the peculiarities of AVC and QAVC circuits and obscure receiver troubles, with a useful chapter on repairing individual radio components.

The concluding part also has chapters on reducing electrical interference, high fidelity receiver problems, and, of particular interest to professional servicemen, "How to sell your service."

It is difficult to do justice in a short review to a book of this nature, which can only be described as encyclopaedic. In his preface, the author states that he does not assume that all readers will read the book through in its entirety. This is possible, but having bought a copy they will be continually dipping into it and finding something interesting and of real practical use. In spite of its bulk it is well-bound and a pleasure to handle.

Manual of Direct Disc Recording

D. W. Aldous 49 pp. 36 figs. (Bernards (Publishers) Ltd. 2/- net).

A booklet of useful data on disc recording, which has been the author's special study for some years. The notes are arranged alphabetically, and there is a section on defects in recording and their causes, together with a glossary and bibliography. A copy of an errata slip can be obtained from the author c/o the publishers.

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Signals for the Home Guard

J. H. A. Whitehouse, 77 pp. (Practical Press Ltd., 3s. 6d. net).

Many books have been written on signalling for the Home Guard, usually including much information already available in the excellent series of official publications "Signal Training All Arms," but this new work, as the author, a well-known Signals Officer in the H.G., mentions in his foreword is concerned only with those essential administrative and technical design problems peculiar to the H.G., and on which there is neither official information nor recognition, financially or otherwise.

Such topics as the signalman's job and training methods field telephone lines, switchboards, signal lamps, buzzer and magneto telephones, as well as a short section on the use of radio apparatus, are covered in the ten chapters, which reveal much useful information, obviously gained from considerable practical experience. Constructional details of such devices as (a) simple cordless exchange, (b) field Morse telegraph unit, (c) visual signalling lamps, (d) patrol type field telephone, made from "junk" or converted old equipment to the designs of the author, are given with plentiful diagrams and illustrations.

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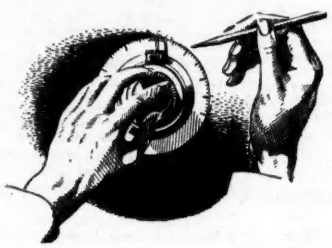

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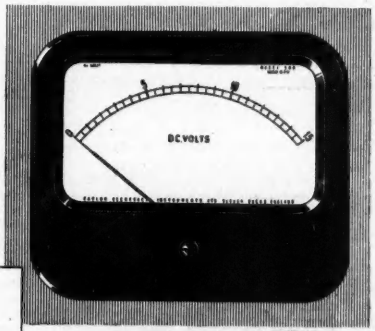

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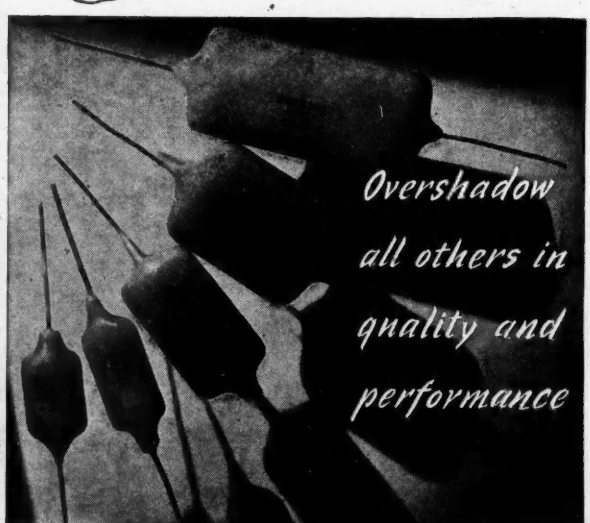

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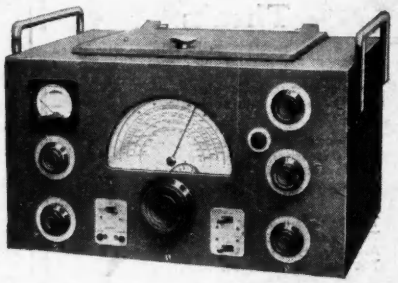

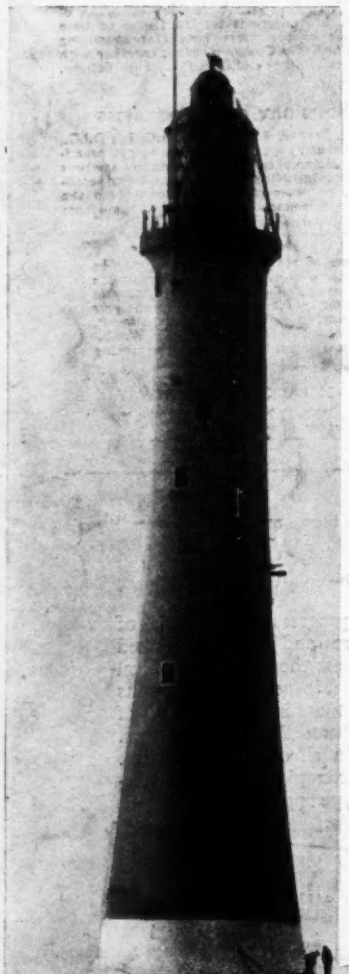

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